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From the Editor

by Doug Hendricks, KI6DS
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This is an exciting issue for me. With it, we are back on schedule for delivering QRPp. Thank you for your patience and understanding.

But the real reason is the quality of the articles. I would like to point out 4 of them. Larry East's Cub Mods article, Mike Fitzgibbon's Iowa QRP 10, Building the St. Louis Coil by Andy Becker, Dave Gauding and Paul Harden, and George Heron's PSK31 Station. These four articles are as good as we have ever had in QRPp. All of the credit must go to the authors and Paul Harden for his illustrations.

Speaking of Paul Harden, I would like to publicly thank and recognize Paul for his outstanding illustrations both in this and past issues of QRPp. His work is to be treasured. Without his illustrations the St. Louis Coil and Iowa QRP 10 would be difficult to build at best. With them, they are easily accomplished. That says it all in my opinion. Thank you Paul.

One quick correction. Joe Everhart deserves the credit for thinking of the idea of the NJ QRP Club kitting the cases for the SMK-1 Kits. I had attributed that idea to George Heron in the last issue.

See you in the winter issue to be mailed the first week of January 2001. 72, Doug, KI6DS

Modifications for MFJ QRP-Cub Transceivers

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*Editor's note: Larry's Cub mods originally appeared in the July and October 2000 issues of the **ARCI QRP Quarterly**. Since many of our readers don't receive the **QRP Quarterly**, I asked him for permission to reprint them in **QRPp.***

Introduction

The MFJ QRP-Cub series of single-band transceiver kits are fun little rigs to build. Most of the components are "surface mount" type and already installed. The remaining "through hole" components can be installed very quickly – and there are only two toroids to wind! Output power is on the order of 1 to 3 watts, depending on the band model. The design is quite basic and there are no "frills" such as RIT, frequency enunciator or built-in keyer. AGC (audio derived) is included, however.

I purchased a 15M kit mostly out of curiosity; considering the assortment of QRP rigs that I have including a recently completed Elecraft K2, I really don't need another radio (at least according to my XYL...)! As soon as I had it up and running, I found a few things that needed "improving". In particular, I found that the receiver recovery time was too long for my tastes. The tuning range was about 62 kHz, and I found that tuning with a single turn pot was very touchy. The "fixes" for these and a few other items that I implemented in my Cub are described in this note.

Tuning Linearization

As is common with varactor tuned VFOs, the Cub tuning is not very linear; frequency spacing (i.e., kHz/degree of tuning pot rotation) is quite a bit finer at the low end of the VFO tuning range than it is at the high end. The tuning linearity can be greatly improved by simply placing an appropriately sized resistor from the wiper of the

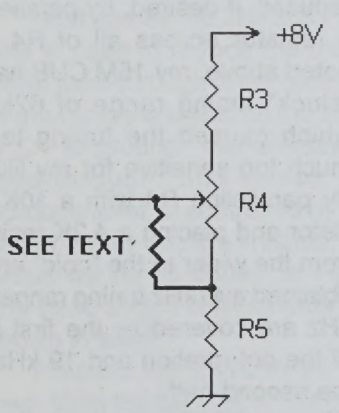

Fig. 1 Resistor added to linerize tuning.

tuning pot (R4) to the "cold end" of the pot (the end that connects to R5). This connection is shown in **Fig. 1**. The "appropriate size" depends on the particular band model that you have, but a good starting point is 4.7K. There are extra holes for the pot connections, so it's very easy to solder a

resistor to these holes on the bottom of the board. Probably the best approach is to tack-solder in a 10K pot, adjust it until you get approximately the same frequency spread on the first and second half of the rotation of R4, measure the pot value, and replace it with a resistor that comes closest to the pot value.

The shunt resistor will reduce the total tuning range slightly, perhaps 10 kHz or so for a resistor in the 3-5K range and more for a smaller resistor. (There will be less effect on the 30M model since it has a smaller initial tuning range.) The tuning range may be further reduced, if desired, by paralleling a resistor across all of R4. As noted above, my 15M CUB had a "stock" tuning range of 62kHz, which caused the tuning to be much too sensitive for my liking. By paralleling R4 with a 10K resistor and placing a 4.2K resistor from the wiper to the "cold" end, I obtained a 41kHz tuning range; 22 kHz are covered by the first half of the pot rotation and 19 kHz by the second half.

"True QSK" and Related Changes

I made changes to the keying circuit to reduce receiver recovery time and improve the transmitter keying envelope. I also added a pot to adjust the sidetone level. These changes are interrelated and should be performed together.

No circuit board traces need to be cut, but one surface mounted resistor must be removed. Only six additional parts are required:

1. 2N7000 FET (Mouser Part No. 625-2N7000)
2. 10µF 10V tantalum capacitor (Mouser Part No. 74-199D10V10)
3. 0.22µF small ceramic capacitor (Mouser Part No. 581-UEZ224K2)
4. 2K 1/4-in. (7mm) square potentiometer (Mouser Part No. 72-T70YU-2K)
5. 10K 1/4 W resistor
6. 2.2K 1/4W or 1/8W resistor (1/8W preferred)

It is not absolutely necessary to remove the board from the case, but it is probably more convenient to do so. A good magnifying lamp and/or "cheater glasses" will be very helpful; but if you are like me, you needed those to build the kit in the first place!

Start by removing R30. This is a 4.7K SMT resistor located near the right-rear edge of the PC board (near C34). You can take the brute-force approach, break the resistor in two with a pair of small cutters or diagonal pliers, and then remove the pieces from the pads with desoldering wick. Or, with a little effort, fine desoldering wick (0.020 – 0.030 in.) and a small prying tool (like a Dentist's pick), you can remove the resistor in one piece. First, remove as much solder from both pads as possible using desoldering wick. Then gently pry up on the resistor as you heat one pad and then the other. The resistor should pop off in one piece.

Next prepare and mount the 2K trim-pot; this will be the sidetone level control. Prepare the pot as follows: Looking at it from the rear, bend the left-hand lead over to the center lead, wrap it around the center lead and solder it. Trim any excess wire from the left-hand lead (*not* the center lead; you need it full length.) If the style of pot that you have has the three leads in a straight line, then the up/down orientation of the pot is not important. If the center lead is closest to one edge, orient the pot with the center lead nearest the bottom edge before making the above connection from the left-hand lead.

Now comes the somewhat tricky part: mounting the pot on the board. If you look just behind and between L1 and L2, you will see a plated-through hole in the board just behind C13 and between Q1and C31. This connects to the ground plane on the bottom of the board. You want the center lead of the pot to go through this hole, with the pot sitting on top of C19 and C31. Be very careful not to short anything! Once the pot is properly positioned, solder the center lead in the ground feed-through. The pot can be kept in place by applying a little bee's wax to top edge of the pot nearest Y1, then use your soldering iron to melt the wax to secure the pot to Y1. You can also use hot glue (or some other adhesive), but bee's wax is very easy to remove without damaging anything if the need should ever arise.

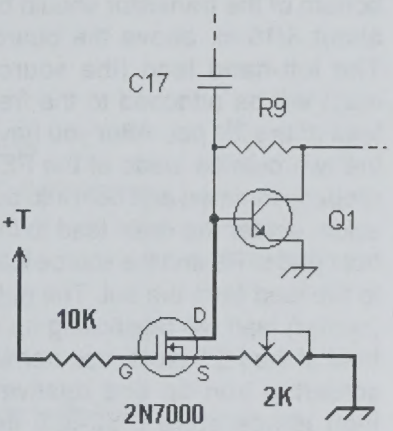

Fig. 2. Components added for adjustable sidetone.

Next comes the 2N7000 FET. This is used to reduce the transmitter feed-through in the receiver by shunting the signal on the base of Q1 to ground. The amount of feed-through, and hence the sidetone level, is controlled by the 2K pot. When you are finished, the circuit will be as shown in **Fig 2** (the three added components are shown in **bold**).

Prepare the 2N7000 as follows: With the flat side of the transistor facing you and the leads pointed down, bend the left-hand lead up beside the transistor body. Bend the center lead up in front (the flat side) of the transistor. You now need to carefully solder the remaining lead (the right-hand one, which is the drain lead) to the front pad of R9 (the pad that connects to C17 and Q1). Shape the lead so that a short section will just fit over the solder pad of R9. The

bottom of the transistor should be about 3/16-in. above the board. The left-hand lead (the source lead) will be attached to the free lead of the 2K pot. After you have the two outside leads of the FET properly trimmed and bent into position, solder the drain lead to the front pad of R9 and the source lead to the lead from the pot. The gate (center) lead will be sticking up in front of the FET. **Note:** use a small soldering iron tip and relatively high temperature (750-800 degrees F) when soldering to the R9 pad and be quick! Hold the wire from the FET on the pad and touch the iron to the lead only long enough for solder to flow from the pad to the wire. After you have secured the FET in place by soldering the other lead to the pot, you can use a little solder if necessary to touch up the connection to the pad. Again, leave the iron on the pad only long enough to get the solder to flow. If you get too much solder on the pad, remove the excess using desoldering wick.

Next, locate the two feed-through holes between R19 and C27. The hole nearest R19 connects the "+T" line from the top to the bottom of the board; this is the one that you want. The 10K resistor connects between this hole and the gate (center lead) of the 2N7000. Bend one lead of the resistor at a right angle about 1/4-in. from the resistor body. Feed the bent end of the lead into the hole and trim the other lead so that it can be soldered to the gate lead of the FET. The resistor should be positioned about 3/16-in. above and parallel to the board. (If you did not remove the board from the case, trim the bent resistor lead so that it will not extend below the board and short to the case. Otherwise, you can trim the lead after it is soldered.) Solder the resistor in place and trim any lead excess.

Now solder the 2.2K resistor between the front of R28 and R29 (immediately to the left of C27); see **Fig. 3**. The pads to which you will solder the resistor are the ones that connect to Q8. The resistor should be positioned on top of R28 and R29 with the leads bent to touch the two solder pads. A 1/8W resistor works best for this, but a 1/4W one can also be used. Again, be careful not to heat the pads to long or be sloppy with solder.

When you have the 2.2K resistor in place and the leads trimmed, solder the 0.22µF capacitor between the front pad of R29 (the same one to which the 2.2K resistor is attached) and the lead of the 10K resistor that passes through the PC board. The 2.2K resistor and 0.22µF cap are used to shape the rise and fall time of the CW keying waveform. Without these components, the CW envelope rise-time is very fast (about 0.1ms) resulting in minor but noticeable key-clicks. With these added components, the CW envelope rise and fall times will be about 2ms yielding very nice sounding keying.

Now all that is left to do is solder

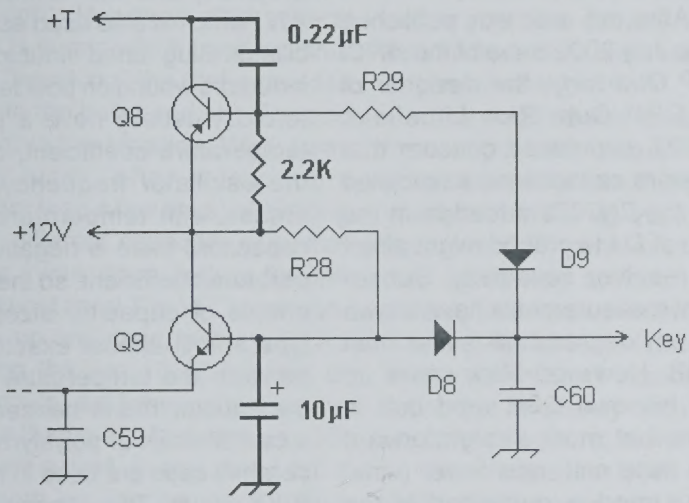

Fig. 3. Modified T/R keying circuit. Added components are shown in Bold.

the positive lead of the 10µF cap from the pad of D8 that connects to Q9 and R28 and the negative lead to ground. For the ground connection, use the feed-through hole between D5 and C60. The new Q8-Q9 switching circuit will be as shown in **Fig. 3** (added components are shown in **bold**).

The 10µF cap ensures that the T/R switch (comprised of D4-D7) remains off a few milliseconds after transmitter output decays to zero so that no "thumps" or "clicks" will be heard in the sidetone. However, the receiver will still recover very quickly allowing full QSK operation.

The long recovery time of the receiver in its stock form was due to the AGC being blocked during transmit by a voltage applied to it through R30. However, if you just remove R30, the sidetone will be extremely loud and will still activate the AGC. The FET shunt from the base of Q1 to ground eliminates this problem.

Carefully check your work for solder splashes, connection errors, etc. When you are satisfied that all is well, set the 2K pot to the middle of its range, connect the rig to a power source, key, dummy load and headphones. Apply power and key the rig; the sidetone should not have any "clicks" or "thumps" and the receiver should recover almost instantaneously on key-up. If not, then it's time to retrace your steps! If all is well, set the desired sidetone level with the audio pot set for a comfortable level for re-

ceiving and enjoy true QSK operation!

After this mod was published in the July 2000 issue of the ***ARCI QRP Quarterly***, the designer of the QRP Cub, Rick Littlefield, K1BQT, expressed concern that the extra capacitance associated with the 2N7000 added from the base of Q1 to ground might affect the receiver sensitivity. Subsequent measurements have shown that any degradation is less than 0.5dB. However, Rick came up with his own QSK mod that is somewhat more straightforward than mine and uses fewer parts. Rick's mod is published in the October 2000 issue of the ***ARCI QRP Quarterly*** (page 17) and on the ARCI web site (www.qrparce.org). If you use Rick's QSK mod, you should still install the 0.22µF capacitor and 2.2K resistor shown in **Fig. 3** to improve the keying envelope. However, the 10µF capacitor from the base of Q8 to ground (shown in **Fig. 3**) will not be required, nor the changes shown in **Fig. 2** unless you want to be able to adjust the sidetone level.

VFO Warm-up Drift

Some Cub owners have noted significant warm-up frequency drift, whereas others see very little drift. Such variations are to be expected due to the normal production tolerances of the parts used in the VFO.

The major sources of possible drift in the Cub VFO besides the inductor and capacitors used in the circuit are the "tuning diode" (D2, an MV2104) and the SA602 mixer (U2) which is also used as the oscillator. Slug tuned inductors (and inductors wound on powdered iron toroids) usually have a positive temperature coefficient, causing the oscillator frequency to decrease with temperature. Most capacitors have a negative temperature coefficient, so the proper choice of capacitor size(s) and type(s) will almost exactly compensate the temperature drift of the inductor; this is the reason that a combination of polystyrene and ceramic caps are used in the Cub VFO circuit. The capacitance of the tuning diode is a small part of the total VFO circuit capacitance, hence its contribution to drift is small. The contribution of the SA602 to the VFO drift can, however, be significant. Unfortunately, the thermal properties of the various components can vary from device to device making it difficult to come up with a temperature compensation scheme that will work in every case.

In its "stock" form, my 15M Cub would drift down about 2 kHz during the first 10 minutes after a "cold start" and another 300-500 Hz over the next 5 minutes. It then settled down and would maintain a set frequency within a couple of hundred Hz or so over the next hour or two – provided the ambient temperature remained relatively constant.

Since temperature compensating a VFO can be a long and

frustrating exercise, I tried to convince myself that this was "good enough". However, after several QSOs during which I was continually "tweaking" the dial, I decided to bite the bullet and see if I could improve the situation. Well, I was very lucky; after a few hours (rather than a few days) of diddling with different capacitor combinations, I was able to reduce the drift to almost zero! The VFO now wanders up and down about ± 50 Hz during the first 10-15 minutes of warm-up, and then changes no more than ± 25 Hz during any 10-minute period. In one test, I left it running on the bench for four hours and the total drift was only 90 Hz. It did drift up and down some during that time, but never the less, this is a ***big*** improvement over the original drift!

The improvement was achieved by replacing C6 (originally a 150pF "mono cap") with three caps in parallel: A 100pF NP0 mono ceramic, a 10pF N900 disc ceramic and a 39pF NP0 disk ceramic (the two disk caps are soldered on the bottom of the PC board). For those not familiar with capacitor designations, "NP0" caps have very low temperature drift; typically less than ± 100 PPM per degree C. (The "mono" caps used in the Cub are supposed to be NP0.) "N900" means that the drift is "nominally" a negative 900 PPM per degree C. As explained above, this combination of capacitors may ***not*** work for your 15M Cub, and certainly not for other band models.

If you want to try to reduce the drift in your Cub (or any VFO, for that matter), here are a few things to keep in mind:

- You won't be able to make any meaningful drift measurements immediately after touching a soldering iron to the rig. Let it sit with the power OFF for at least 30 minutes (preferably an hour) before making drift measurements.
- The 80 and 40M Cubs use "down conversion", meaning that the output frequency drift is in the opposite direction to the VFO drift.
- Some capacitor types – especially ceramic caps that have sat in a parts bin for a few years – need to be "conditioned" for several minutes to an hour or more in an operating circuit before they completely stabilize.

The best way to check for drift is with a frequency counter. You can also monitor the VFO on another receiver, but this is less precise. In any event, make sure that your measuring device is relatively stable; trying to check for VFO drift using a receiver that also drifts is a rather hopeless endeavor!

Ceramic capacitors that have a fairly linear negative temperature coefficient are designated "N470", "N750", etc. – the number indicating the nominal PPM/deg-C temperature coefficient. NP0 (also called C0G) caps have a temperature coefficient that is ideally zero, but in practice they may exhibit small positive or negative coefficients (more likely nega-

tive in my experience). NP0/C0G caps are available from most parts suppliers (Mouser, Digi-Key, etc.). N750, etc. caps are rather difficult to find, although some are often included in capacitor assortments sold by Radio Shack and others. Digi-Key carries Philips "N750" ceramic disk capacitors that have a specified temperature coefficient of (–1000 ± 120)PPM/deg-C. Polystyrene capacitors have a small negative temperature coefficient of about 150 PPM/deg-C and are available from many parts suppliers. Silver mica caps have small (but usually unspecified) positive temperature coefficients.

If your Cub VFO decreases in frequency during warm-up, replace a polystyrene cap used for C6 or C7 with an equal value combination of NP0 and N750 (or poly) caps. If the direction of drift reverses, use a larger poly (or N750) cap and a smaller NP0 cap. If the drift is still down in frequency, try changing both C6 and C7 to combinations of NP0 and poly or N750 caps. You can also replace mono caps used for C6 (or C7) with combinations of NP0 and N750 (or poly) caps to reduce a negative frequency drift (this is the approach that worked for me).

If your VFO increases in frequency during warm-up, replace a polystyrene cap used for C6 or C7 with an equal value NP0. If the drift direction reverses, try combinations of NP0 and poly (or N750) caps to minimize the drift. If it is still positive, try silver mica caps (which have a small positive temperature coefficient) in combination with NP0 (or poly) caps.

A Potential Source of Chirp

After solving the VFO drift in my 15M Cub, I noted that the VFO frequency shifted slightly (~40 Hz) when the rig was keyed. I noted a similar change in VFO frequency under key-down conditions while changing the output power from zero to maximum (about 1.2W for my rig). Probing a little further, I found that the VFO frequency was sensitive to supply voltage; a 1V change produced a 700 Hz change in VFO frequency. The slight drop in the +12V supply line (~0.05V) when the transmitter was keyed resulted in the small frequency shift that I noted.

By the process of elimination, I finally determined that the VFO buffer, Q4, was the cause of the problem: JFET gate capacitance is a function gate-source voltage. Since Q4 is supplied by the "raw" 12V supply, any change in supply voltage results in a small change in the gate-source voltage and hence gate capacitance. Since the gate is connected via a couple of caps directly to the VFO tank circuit, a change in the gate capacitance will change the VFO frequency! The obvious cure is to supply Q4 from the regulated 8V output of U1. I removed R16 and connected the drain of Q4 to the output of U1 via a 47-Ohm resistor (100 Ohms would also work). After that change, the VFO frequency shifted less than 10 Hz for

a supply voltage range of 11.5 to 14V! And no detectable frequency shifts (<5 Hz) when keying the rig or changing the power level. Problem solved!

The VFO frequency sensitivity to supply voltage shouldn't normally be a problem unless you are running your Cub from a power supply with poor regulation. Under such conditions, some "chirp" might be detectable on the transmitted signal.

The "fix", however, is easy to implement. First, remove R16, either by breaking it and removing the pieces, or unsolder it using a fine-tipped iron and solderwick. Then solder a 33 to 100 Ohm resistor (1/8W works best, but 1/4W can be used) between the R16 solder pad that connects to the drain of Q4 and pin 1 of U1 (the end of C3 that connects to U1 pin 1 is a convenient soldering point). The VFO frequency range will change slightly after this mod due to the lower drain voltage on Q4; you may want to adjust L3 if the shift is significant.

Improving AGC Strong Signal Response

My Cub's AGC would "pump" badly on strong signals. Let me try to explain what I mean: When a very loud signal was present, the first character (dot or dash) caused a momentary (apparent) depression in audio gain (that's what I mean by "pumping"). The gain quickly recovered to the level set by the AGC and stayed there as long as the strong signal was being keyed within the recovery time of the AGC. This "pumping" was in addition to the slight "pop" or

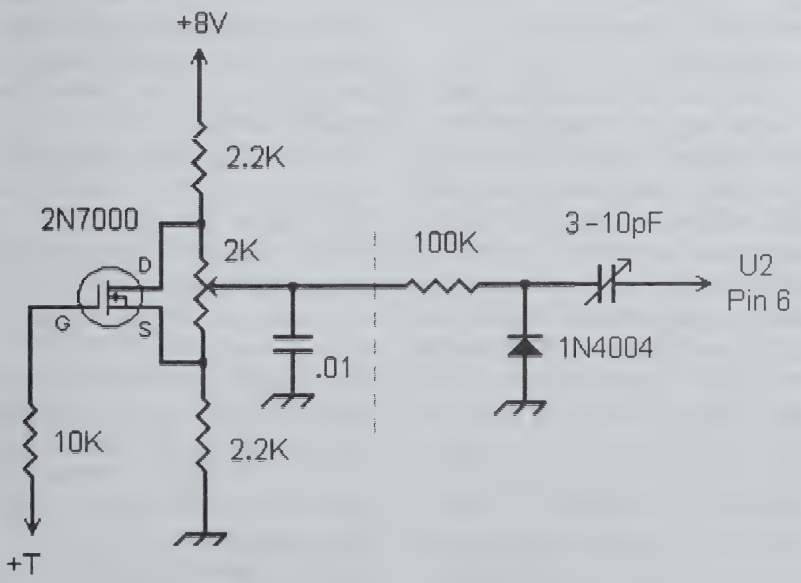

Fig. 4. Simple RIT circuit for the MFJ Cub.

"thump" on strong signals that is characteristic of audio derived AGC.

I increased R13 to 6.2K and that significantly reduced the initial gain drop, but (of course) the initial "pop" is still there. I found that my BFO was a little off, resulting in too much low frequency response. I reset it so that the IF filter passband peaks in the 700-800 Hz range and that also helped.

So... If you are experiencing AGC "pumping" in your Cub, first make sure that the BFO is set correctly and then try increasing R13 to something in the range 5-10K. (I used 6.2K just because I happen to have some 6.2K surface mount resistors in my "junk box"; a "through-hole" 1/8 W resistor can also be used.) I didn't try replacing R13 with a pot and attempting to find an optimum value.

Adding RIT

Maybe I'm just spoiled, but I really missed not having RIT in my Cub. There are many RIT circuits that can be adapted to the Cub, but the limited space for added components led me to use the simple circuit shown in **Fig. 4**. The circuit is certainly not original, but I don't recall where I first saw it. A 1N4004 is used as a "tuning diode"; reverse voltage applied to it via the 2K pot varies it capacitance. The 1N4004 is coupled to the VFO via a small capacitor. I used a mini trimmer (Digi-Key part number SG1022-ND) to allow the RIT range to be set (a total range of 3-4 kHz is about right). However, a small fixed NPO capacitor can also be used; 10pF will probably be required for the 20M version, and 4.7 – 6.8 pF should work for other versions. The 2N7000 is used as a switch to set the voltage on the 1N4004 to "mid range" during transmit, thus disabling the RIT. The original circuit used an NPN transistor switch, but the small collector-emitter voltage present when the transistor was conducting resulted in the RIT having a slight effect on transmit frequency. The very low on-resistance (less than 10 Ohms) of the 2N7000 MOSFET completely eliminates that problem (a J309 or similar JFET should also work).

Note that there is no RIT on/off switch shown; if you wish to add one, use a SPDT type to switch the MOSFET gate resistor between +12V (disabled) and +T (enabled). I used a center-detent pot for the RIT control and did not find a switch necessary.

The RIT pot resistance can be anything between 1K and 10K. The resistors connecting it to +8V and ground should be approximately the same value as the pot and matched to each other to within a few percent.

The components to the right of the dotted line in **Fig. 4** should be mounted on the PC board using very short leads. I soldered one end of the trimmer cap to the solder pad of C6 that connects to U2 pin 6 and bent the other tab upward. The 1N4004 and 100K resistor were soldered to the upward-

pointing tab, and the anode of the diode was grounded to a ground feed-through to the rear of U2. I mounted the other components on a small piece of "perf board" and attached it to the RIT control solder tabs.

The "+T" control voltage can be obtained at the junction of R21, R23 and C43; simply solder a wire to one of the component's solder pads.

I mounted the RIT control in the upper left-hand corner of the front panel. The MFJ logo in that position can be easily removed, if desired, using denatured alcohol.

During initial testing, you may wish to ground the 10K resistor from the MOSFET gate rather than connecting it to +T. This will result in the RIT being enabled during transmit so that you can check the RIT range by measuring the transmit frequency. The RIT range will not be symmetrical; there will be about 20% more VFO offset on the low-frequency side than on the high side.

After the RIT circuit is installed, you will need to readjust L3 for the proper frequency range.

Odds and Ends

Resettable Fuse

The "fuse" in the Cub is simply a trace on the PC board that is supposed to open under high current conditions. (Look for a "zigzag" trace near the power connector.) There are solder pads at each end of the trace so that a #30 wire jumper can be installed should the trace ever open. You can also cut the "fuse trace" and install a real fuse, such as a 0.5A subminiature axial lead type, using these solder pads. I chose to install a "PolySwitch" resettable fuse so that I won't have to bother with replacing it should I ever have an over-current condition (caused, for example, by a reverse power connection). These are solid-state devices that have a very low resistance until a current threshold is reached and then the resistance becomes very high. They will remain in the high resistance state until the over-current condition is corrected. Slick. These devices are fairly inexpensive and avaiiable from Digi-Key. The part number for one that will trip between 0.5A and 1A is RXE050-ND.

Tuning Calibration

Unless one uses an external frequency counter or other measuring device, determining the Cub's operating frequency is pretty much a matter of guesswork. There is not even a "logging scale" for the tuning dial that one can use to make a calibration chart. (Dial tick-marks are shown in the picture of the Cub on the ARCI web site, but apparently those didn't make it into production...) I like to know where I am operating, so I decided to make a "custom dial" using an inkjet printer and clear self-adhesive film. The film that I used is called "Repro Film" manufactured by Rayven Inc. This and similar film can be obtained from stationary stores and copy centers. I find it very useful for transferring

lettering to panels. After the film is applied to the panel, I coat it with a clear acrylic spray coating.

Power Output Notes

My 15M Cub puts out about 1.2W when powered from 13.8V. The manual states that power output can be increased somewhat (up to 20%) by using a different RF power transistor in place of the 2N5109 supplied with the kit. I tried two different 2N3553's and one 2SC799 and did not see any significant improvement. The output was slightly less with one of the 2N3553 and slightly more with the other compared with the stock 2N5109. The output from the 2SC799 was significantly less at about 0.8W. The 2N3553 with the greatest output (about 1.3W became unstable when I accidentally keyed the rig with no antenna connected. I found no indication of instability with the other '3553, the stock 2N5109 or the 2SC799.

I suspect that there is not enough drive, especially on 15M, to provide much more output than can be obtained from the stock 2N5109 (an MRF237, however, might provide a little more output because of its higher gain). The little surface mount PN2222A driver transistor could perhaps be replaced with a more robust 2N2222A, 2N4401 or 2N3904 to provide a little more gain, but I didn't try that.

My personal opinion is that any power increase obtainable by hand picking driver and final transistors would likely be less than 50% and not worth the effort. Any contact that can be made with 1.5W can probably be made just as well with 1.0W. Keep in mind that any circuit changes made in an attempt to increase power output run the risk of increasing spurious emissions as well.

QRP Operating News

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Anyone who has ever been in the chase for DX at QRP levels knows that operating skill is a major part of the formula for success.

Even under not-the-best-of band conditions, some amazing distance work has been done by low power operators.

As you'll see in this quarter's column, having a solid and well-thought strategy is one of the elements for making things go your way.

QRP DX: Some sage advice

James Duffey, KK6MC/5, writes from Cedar Crest, NM that he is "not an avid DXer, but I try to work it if I hear it. Here are some tips that I find useful. They may or may not apply to (every QRPer's)

situation, but I think somebody may find them useful."

Tip 1: If you don't already have it, get a copy of Bob Locher's, W9KNI, "The Complete DX'er," (2nd Edition, ©1989 Idiom Press, Deerfield, IL). It is chock full of good tips. In a quick perusal of my ham library (located in three different places in the house) I was unable to find my copy. (Now, who did I loan it to?)
It is chock full of tips that will help you work DX.

Tip 2: You have to be on the bands to work DX, so get on as much as you can, even when the bands are rotten.

If you have trouble getting on, encourage yourself by putting a piggy bank on your operating desk and dropping a dollar bill in it every time you start an operating session.

You can pay for a K-2 in a little over a year and a half of daily operating this way.

Tip 3: Get on the bands at unusual times.

Go to bed an hour earlier and get up an hour earlier to operate around sunrise.

The bands are different then and you will have entirely different DX to chase.

Also you can take advantage of greyline propagation. Instead of going to bed on Friday or Saturday night after returning from a night out, brew a pot of coffee, get on the air, and operate in the wee hours.

Tip 4: Nearly every DXer will tell you that listening is the key to DXing.

I agree, but you need to get on to listen so I emphasize getting on first. You need to listen with a purpose.

Develop a listening plan. I start on the highest band open, since absorption will be lowest and a QRP station will have the best chances for getting a contact.

I start at the low end of the band and go up. Listen to every station on the band.

Determine where the station is and who the station is talking to. Finding a domestic station working DX is almost as good as finding a DX station.

Listen for keys to DX: weak signals, fluttery signals, signals with a poor note, and a domestic station with excitement in the fist from working a new one.

After you have gone from one end of the band to the other, reverse directions and listen again. If I have not uncovered un-worked DX after a few trips up and down the band, I go to another band.

Not every DX station has a pileup, so I think that this way of listening is more effective than merely looking for a pileup.

Tip 5: It helps to keep a list of those stations you have worked and those you have QSLs from as you listen on the band.

You can do this on paper, or

some computer programs will track this information.

If you hear a station you need and can't work him right away it helps to put him in a memory.

Or note what frequency he is on, so you can work him later.

Tip 6: DXers, like you and I, are creatures of habit.

If he was on a certain band at a certain time one day, the chances are good he will be on at roughly the same time, and band, on another day.

Tip 7: Knowing when to listen is helpful. If you don't have or use a propagation program I suggest getting one and using it.

It will tell you statistically when the band is open to where.

It doesn't do much good to look for DX on a band that doesn't support DX.

Also, monitoring the NCDXF beacons help to tell you if the band is open, and to where the band is open.

Tip 8: If there is a DX packet cluster in your area, monitor it for DX alerts.

This information is also available on the Net, but is less localized, so you need to wade through a lot more posts to find something useful.

Before the DX Clusters were around, many stations announced DX on the local repeater or gave a friend a phone call when a new one came up.

You might get some of the more avid DXers in your area to help you out this way.

Tip 9: Now would be a good time to upgrade if you don't have an Extra Class license, as there is lots of DX in that lowest 25 kHz.

With high CW speed no longer a requirement for the Extra, those DX rich portions of the band should be within every QRPer's reach.

Tip 10: As many QRPers found out in the IARU contest, contests are a good source of DX.

Thirteen new ones in a weekend is a pretty good accomplishment, particularly given the summer conditions.

There are several fall / winter DX contests which should have better conditions.

If you are looking for countries, do not expect to operate the contest as you normally would.

Search and pounce, and only work those new ones you don't have QSLs from.

In the early stages of the contest the pileups will be horrendous, but you may have some luck working them, particularly on the higher bands.

At the end of the contest the big contest stations, even the rare ones, will be begging for contacts and there will be relatively little competition for their affections.

Tip 11: Some contests are better than others for new ones.

the ARRL DX contest is good, as it is the World working the U.S.

The CQ DX contests are good as they take place over holiday weekends so you can plan your sleep around the contest.

When 10 meters is open, the ARRL 10 Meter contest is very productive for new ones.

Tip 12: Many of the big gun contesters set up a few days prior to the contest, and they can often be worked then.

This is particularly true for those big gun East Coast DXers who go down to the Caribbean and operate from exotic islands with special stations during contests.

Tip 13: Some big contest stations don't QSL contest QSOs as they work so many stations in a contest, so work those countries you don't have QSL cards from as often as you can (different stations / bands of course) in hopes that at least one will QSL.

Tip 14: Many contesters run multi-multi stations, which means that they have a station going on each band around the clock, whether the band is wide open or not.

You may be able to take advantage of this by working long path during a time when the band is not normally open and there is not much activity.

It is surprising where 10 meters can be open to at 0300 (local) in the morning when somebody is on there.

Tip 15: Being a contrarian also helps a bit in contesting.

A big contest takes a lot of the competition off the streets.

Working DX on the WARC bands during the ARRL November Sweepstakes is a good strategy, as most avid contesters are also DXers, and the competition is gone, but the DX is still there as they can't work Sweepstakes!

This also works to some extent during regular contests; those DX stations who are not contesters are still on, usually on the WARC bands, and the competition for these stations is reduced as most of the potential competition is off working the contest.

Tip 16: DXpeditions can be useful, but I would concentrate trying to work them during the later parts of the DXpedition, as the big guns are usually out in force during the first stages.

Tip 17: In a contest or DXpedition, I would advise against telling the DX you are working that you are QRP.

That is extraneous information to him. He is trying to put as many stations in the log as possible as quickly as possible, and the QRP information slows him down.

Tip 18: The WARC bands are good hunting grounds as they seem less populated with DX

chasers than the normal bands, but there seems to be as much DX on these bands.

Ten megahertz, or 30 meters, is a particularly good band for QRP DXing.

The power limits, 250 watts, and the fact that most stations have modest antennas, means that the spread between the loudest stations on the band and the weakest is not that great.

Tip 19: There is often DX available on the SSB portion of the band when none is heard on CW, so if all you want are new countries I would also operate SSB in addition to CW.

I know this may be heresy to many readers, but it is true. If you want DXCC, mixed mode is as good as CW only.

Tip 20: I would take a look at your antenna patterns with a program like EZNEC to see if you have any nulls in your antenna patterns.

You can't work DX if you can't put a signal in the DX station's direction.

Depending on what antenna you are using, you may have a peak toward a particular direction on one band, and a null in another one.

You may wish to erect another antenna to fill in any nulls. Good luck in your chase. Having a goal is important in DXing too.

Let us know how it all turns out. We are cheering for you.

Anatomy of a QRP DX QSO

Karl F. Larsen, K5DI, writes from Mesilla Park, NM, that "DX is defined as a station in another country you need for some certificate.

"You can spend a lifetime working on this one and for sure if you're using an invisible antenna.

"Contesting has a short time period and in the case of a Fox, a single station to look for.

"I enjoyed the Summer Fox Hunt pile up at the first of the time period; it is much like a DX pile up.

"The PSK Sprint in September found stations trying to work each other under conditions defined in the rules.

"DX has been very present from Europe on 15 and 10 meters.

"To work these guys you must copy them so you get their callsign and QTH and name while they work someone else.

"Then when they finish with the contact you call the DX with a normal 3x3 and listen.

"If he comes back to another station you relax and wait. Then you again call the DX when he is done.

"This continues with either of two outcomes: You work him, or you quit or he fades out.

"On PSK I have been very lucky. Running 5 watts I have worked Russians with names like Segio, and Spaniards with names like Juan.

"It seems to me that the QRP

group is missing a bet.

"A lot of small rigs are made for 20 and 40 meters. My Ten Tec Argonaut covers also 15 and 10 meters.

"These bands have the DX on them loud enough for a QRP station to work them.

"In the sunspot maximum where we are now, 20 meters is not very special and 40 meters may be far worse than it is during sunspot minimum!

"All contesting DX and otherwise requires that the stations listen most of the time, and to be a success call at the right time and frequency.

"There are many who call even though they don't hear the station they are calling hoping . . .

"You need to keep your cool and not tell a person calling the DX while DX is talking that they have a suspect background.

"You just fume and hope the guy stays off long enough to work this DX running 5 watts."

Milliwatting and the DX chase

Jim Hale, KJ5TF, writes from Kingston, AR that "Friday's mail brought me another DX QSL card!

This one is FY/DJ0PJ who was in French Guiana. He was running 5 watts from a QRP+ to a balcony dipole. I was using my K2, WM-2 and 10 meter quad, running 200 mW.

This QSL brings me up to a nice number in my quest for the Milliwatt DXCC award from QRP ARCI. I now stand at 70 countries confirmed, using from 5mW to 800mW. Some are from contests, and some from non-contest QSOs.

In contests I use hunt and pounce with my own mW twist to it. I have my log handy as I scan the bands, and look for new countries. Then I watch their pileup and choose a time when they have few callers. Even the rare ones have slow moments when a tiny milliwatt CW signal can make it. They are getting hungry for callers and will try hard to copy you. I have a list of all 70 DXCCs on my web page, check it out: www.madisoncounty.net/~kj5tf/ "Have fun!"

IOWA QRP 10

by Mike Fitzgibbon, N0MF
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A simple yet effective ten-meter QRP CW transceiver has long been high on the wish-list of many a QRP operator. The normally anticipated problems in building such a radio—stability, adequate receiver sensitivity, and compact size are, however, actually far from insurmountable. A simple radio for ten meters, based on the now classic *SST* design by Wayne Burdick, N6KR, can easily be constructed by most anyone with rudimentary soldering skills,

a few hand tools, and a bit of patience. The inherent problems associated with placing such a modest design on the ten meter band can easily be overcome with the addition of a few simple circuits and modifications, and it will provide surprising performance.

By employing a varactor-tuned 16 mHz variable crystal oscillator (VXO), followed by a diode frequency doubler and one-transistor amplifier, the same IF scheme utilized by the 20 meter SST (and the homebrewed 15 M version) can be used to tune a bit more than just the standard QRP frequency in the 10 meter band. The radio described herein covers from 28.045 to 28.065 mHz in two ranges with considerable overlap by using two switched tuning diodes. It is dead stable, owing, of course, to the VXO. The frequency doubler/amp circuit is taken from *Solid State Design for the Radio Amateur (an ARRL publication)* and can be found on page 44, fig. 24.

The problem of reduced receiver gain at 28 mHz (compared to SST designs for lower bands) is addressed by adding a simple grounded-gate FET amplifier to the receiver front end. This preamp is a design from the late great Doug DeMaw's *W1FB's QRP Notebook* (page 61, figure 3-18A), and provides about 12 dB of gain. In a recent evaluation at Dave Fifield's radio lab (designer of the NORCAL-20 rig and owner/operator of Red Hot Radio) the prototype receiver displayed an MDS of –138 dBm.

By building the rig Manhattan-style on three small boards, the circuitry easily fits inside a Bud mini-box measuring a scant 5 x 3 x 2 inches. The boards are mounted lengthwise on their sides (vertically) on small right-angle brackets. Built this way, access to all trimmers is maintained, and there is plenty of room for everything with even a bit of extra room left over.

The performance, in the same vein as the SST, is quite good, considering the modest parts count. During prototype "field" testing, several DX contacts were made from western Iowa with the rig's two-watt output, including the Canary Islands, numerous South American stations and Hawaii, all accomplished with a simple vertical dipole hung in a tree at 30 ft. Any day the band is open, east and west coast stations are standard fare from the midwest. It is truly a lunch-box rig that is a real blast to operate, and, owing to the nature of the ten meter band, a for-real miniature DX machine.

Additional notable modifications to the standard circuitry include a sidetone (transmit monitoring) level control, TICK keyer, a three-turn tuning pot, and a MRF237 output transistor. Several other small changes are also made to the basic SST circuit, and will be duly noted in the construction details that follow.

This radio *is* quite simple. On

receive, incoming ten meter signals are first picked off the transmitter's low-pass filter and amplified by the FET preamp. This amplified signal is then fed into U1, the NE602 mixer/oscillator, where the 32 mHz VXO signal is injected. The desired resultant signal at 3.932 mHz, the difference between these two frequencies (32 – 28 = 4), is then passed through the three-crystal filter and fed into U2, the product detector and BFO. Here the signal is mixed with the BFO signal which produces an audio frequency signal. This signal then passes through the two FET switches Q2 and Q3 and is then amplified by U3, a LM386 audio amplifier, to headphone level.

On transmit... the 32 mHz VXO signal is mixed with a 3.932 signal at U4 and the resultant 28 mHz signal is cleaned up by a double-tuned bandpass filter before it is amplified by U5, which also serves as a buffer. This signal is then fed into the transmitter final, a MRF237. Harmonic components are removed from the 2 watt signal by the low-pass filter and sent "out the door". On keydown, the FET audio line switches Q2 and Q3 are shut off by grounding their gates and the desired level of "sidetone" signal (actually transmit monitoring) passes around these FETs through a trimmer resistor, R7. On keydown the input to the RF preamp and the first mixer are also grounded. Keying is driven by a TICK electronic keyer located on the VXO board (see the parts list for supplier).

If you are new to homebrewing or unfamiliar with the SST design it would not be a bad idea to take a look at the original SST article which appears in the spring '97 issue of *QRPp*. Additionally, it is also recommended that you also cast an eyeball or two at the winter '98 issue of this same publication. It contains the excellent 2N22/40 transceiver construction article by Jim Kortge, which is also built Manhattan-style. Jim did a great job not only in building the radio but also in writing it up, and it contains many useful ideas and building techniques.

BUILDING TOOLS AND TECHNIQUE

This radio is built using the Manhattan style. The parts, when installed on the pads, tend to resemble the square-laid avenues and streets of that famous Big Apple isle. That is, the parts rise from the main board like miniature buildings and skyscrapers. Parts are mounted by using small pads of single-sided circuit board which are glued to the main circuit board, which is also single sided (although double-sided will also work just fine). An inexpensive sheet metal punch (see parts list) is used to make these pads, and in this project they are sized 5/32 inch. I found that this size is just about right for most work. Punched any

smaller than this, the copper tends to easily loosen from the fiberglass board material upon heating. This size also works well around the IC sockets, a necessity in this case. The pads are secured with ordinary household superglue. The liquid type of superglue is used and not the gelled variety. The gelled variety takes much longer to set up than necessary.

Before gluing the pads down, it is a good idea to give them a swirl or two on both sides against some medium-fine sandpaper to remove burrs and/or contaminants. Also, a freshly exposed copper surface on the pads will solder more readily. Additionally, frequent use of a small piece of paper towel doused in methanol or a favorite solvent will keep the board clean and body-oil free as you go...so the glue will stick well. And while on the subject of sticking... It is highly advisable to make sure you get the pad just where it should be as you press it down against the board. It takes but a very few scant seconds (like three) for the glue to set up. However, if a mistake is made all is not lost... a pad can be knocked loose by a sharp lateral blow using a flat-bladed screwdriver as a punch. Commercial superglue remover (gelled acetone I believe) can then be used to dissolve the hardened glue on the main board. I use *Duro* brand cement and remover.

The amount of glue needed to secure a pad is a drop about the size of the pad itself, or just slightly smaller. Any more than that—and the pad tends to skate around in the pool as you press it down to the board where it will stick immediately. The pads can be placed onto the glue precisely with a set of forceps (also know as "hemostats") and held with the tip of the jaws or a pencil eraser until the glue sets. I use a set of 5-inch curved forceps for all of my small component lead bending and component placement. They work very well for this type of thing. Having the ability to lock a component lead in the jaws and hold it at any angle with two fingers while soldering is pretty much a basic necessity here. Get a good set of 5 or 6 inch curved forceps...Mouser (parts list) sells a nice set for about $6. Radio Shack sells a set but in my experience they are of inferior quality and do not lock or grip well.

A great deal of the "building" with this radio is simply bending the leads and fitting the parts in a compact, space-saving manner. It may take more that one of these fittings to correctly trim the lead length and bend the wire just right for some of the parts, but the effort and time you invest in doing so will pay off in a good looking machine that works well. This project is easy to construct and get going owing to the simple basic circuits incorporated in this design. If you have a little soldering experience under your belt and have the desire to homebrew a rig this is an excellent place to start.

For a warm up on this type of construction, and especially if you need a circuit to match the crystals for this radio, you may want to build the crystal oscillator from the 1996 ARRL Handbook, pp 27.5. It is called a Crystal Controlled Signal Source. Doing so will not only give you a bit of practice, but also a useful little circuit as a bonus. And, with an appropriate crystal, it can also provide a stable signal source for other projects.

START BUILDING

It is a good idea to first cut and fit the circuit boards and mount the controls and connectors in the enclosure. That way there are fewer surprises. The radio is built on three small boards. The VXO/doubler and receiver boards are identical in size and mounted back to back (glass to glass) on the bottom of the box with threaded 4-40 right-angle brackets. Alternatively, you might try soldering some brass nuts flush with the bottom edge of the boards (a good suggestion by Doug "Da Man" Hendricks, KI6DS). These two boards are 1 7/8" high (mounted vertically) and 4 1/8" long. In addition to the VXO/doubler, and keyer circuit, the center board also holds the voltage regulator and two caps which form the 8 volt supply. This regulator is mounted up high on the board near the "top" edge so connections to it are easily reached after the board is installed in the enclosure.

When mounting the boards in the box you should allow about ¾" height for the components of each of the three boards and mount the boards accordingly. Be sure to give yourself a little space between the ends of the boards and the controls, jacks, etc., to run wires and such. I mounted the keyer annunciator on one-half of the back panel and all the jacks/connectors on the other half. A large, high-efficiency "beeper" (parts list) was used so that I could readily hear it with over-the-ear phones.

A three-turn potentiometer is used to tune the VXO. It provides just the right amount of spread for the tuning range. A single-turn unit might be used, although the tuning would be extremely sharp since the range covered by each tuning diode is approximately ten kHz. A ten-turn pot could also be used, and can probably be found for a buck or two less than the three-turn, but you will do a lot of dial spinning with that set-up. Additionally, if you only want to tune on/near the QRP frequency of 28.060 mHz, you can forget the DPDT switch and second diode and just install the MV209 varactor on the VXO board. The tuning inductor for the VXO is wound on the core using #26 enamaled wire. Don't use wire smaller than this...the core is suspended between the range switch and the VXO board by this wire and wire much thinner than this probably won't be strong enough to support it adequately.

First build the VXO and doubler along with the 8 volt regulator and install this board temporarily in the enclosure with the associated parts (tuning pot and DPDT switch with diodes mounted on its top and bottom (see building diagram). Add an extra turn to the VXO inductor RFC5 when you wind it (make it 27 turns) and then if simply expanding or contracting the windings does not get you in the range you want it is easy to remove one turn. Of the three 10 M rigs I have built all have 26 turns of #26 on the core and tune the same ranges. Also, when mounting C33, angle the trimmer "up" a bit so that it can be accessed from above for adjustment after the transmitter board is installed.

The 1N914 diodes in the doubler should be matched to help suppress the fundamental frequency (16 mHz) at the doubler's output. You can use the "diode check" function of a DVM or alternatively, run a little current through them (10k ohms in series with 12 V will work nicely) and measure the voltage drop across the diode's leads with a DVM on the low range (readings will be .5-.7 volt). Match them within a few millivolts if possible. Diodes from the same "batch" tend to be similar in this parameter so this is not a difficult thing to do if you get a couple of dozen diodes from the same source. They're cheap and commonly used in QRP equipment.

After the VXO/doubler is built test its operation. The VXO oscillator runs on 8 volts and the 2N2222 doubler amp requires 12 volts. Run the grounds on the tuning pot and the switch to the board. Put a scope on the output of the doubler (secondary of T4) and adjust C33 for the best-looking (consistent amplitude) 32 mHz waveform throughout the tuning range of both diodes. This may not be the setting that results in the absolute highest output at any one point, but you should see something around 1.0 V pk-pk or so, depending on the gain of the 2N2222, when it is correctly adjusted. If you don't get any output, check the oscillator for operation with the scope (at C30) or listen with a receiver (set for CW or SSB) at 16.0 mHz. Place the receiver's antenna wire near the board...it will be very audible if it is running.

Just an aside here...I generally check most of the parts before installing them with a DVM, a cap/inductance meter or a transistor tester... I even check the resistors if the markings are small or at all questionable. Then all I usually have to look for is a wiring mistake if it doesn't work...usually...

After you get the VXO going, add the keyer circuit. The IC chip and all the other ICs are mounted in a low-cost machined-pin IC sockets (parts list). The pins are bent at 90 degrees outward so that their ends lie flat on the pads for soldering.

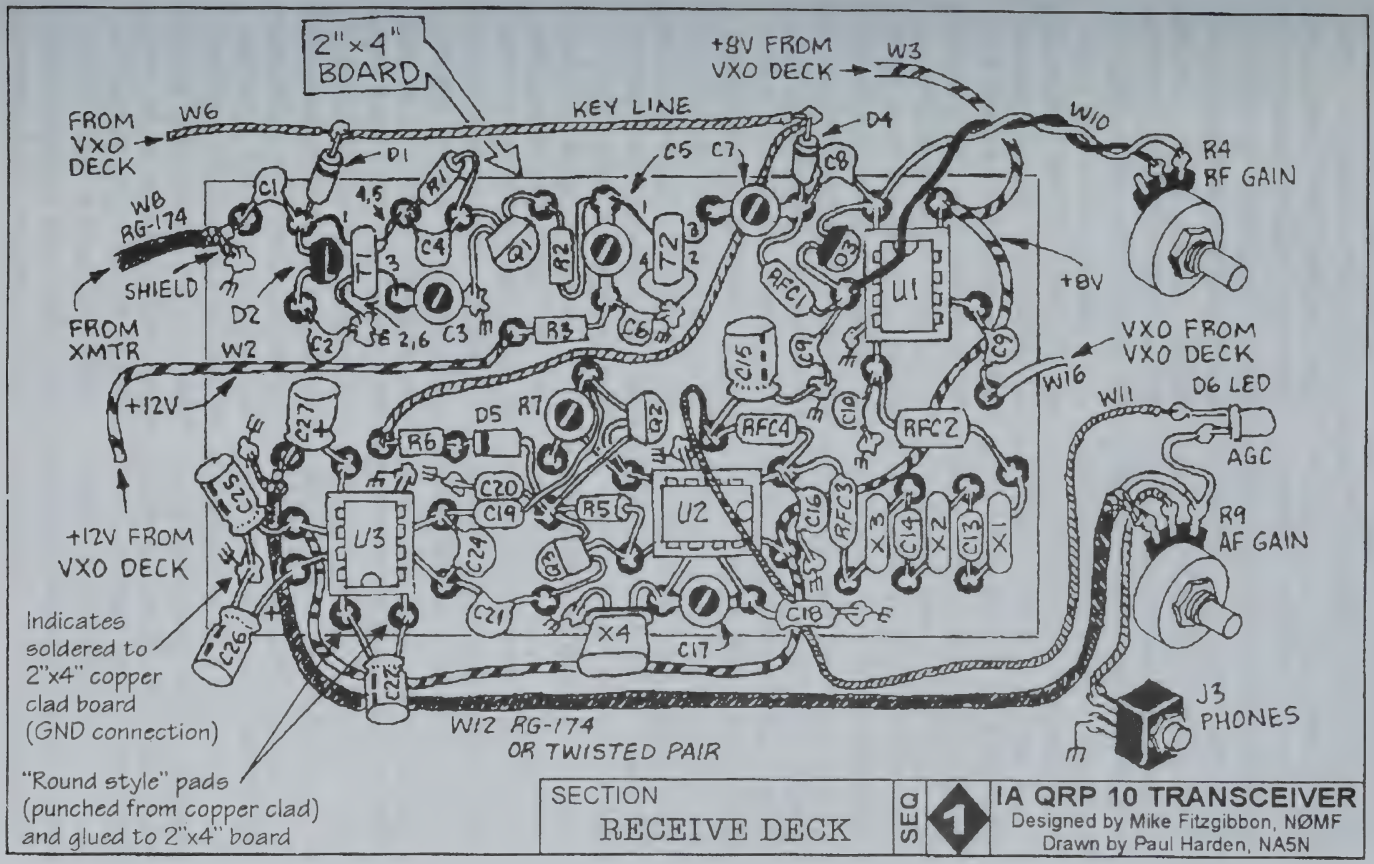
Some general IC socket

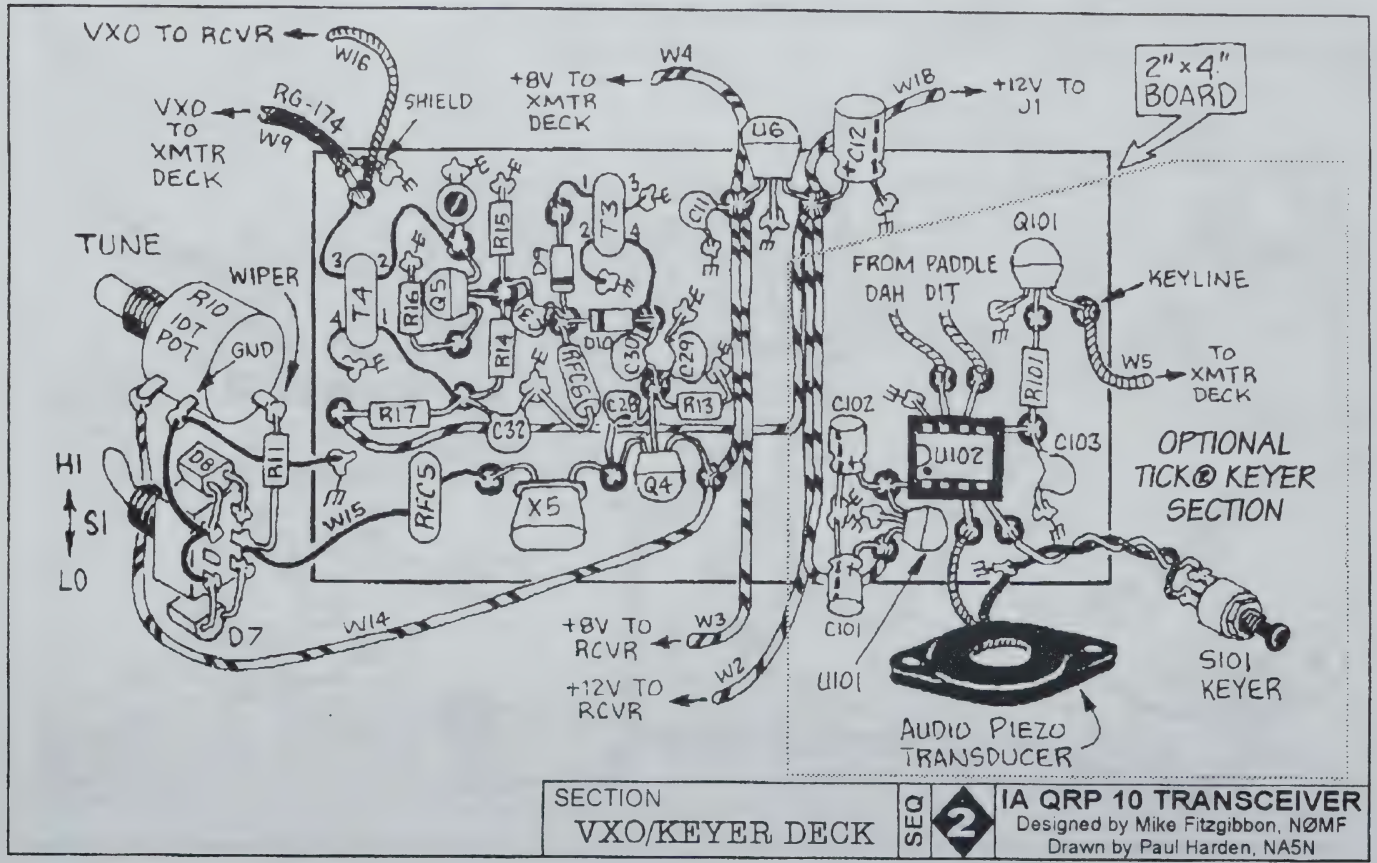
mounting guidelines. One can only bend the pins once...they tend to break if you try straightening them. But...if one of them ends up at an undesirable lateral angle, the whole pin (on these particular sockets at least) can be rotated in the socket body before the chip is installed. If a pin is unused it should be cut off from the socket at the bottom of the socket well. Pins 1,4,5, and 8 should usually be bent out "lengthwise" from the IC socket (see layout) unless they are grounded. These four pins (some or all) are often the main support for the IC, along with any grounded pins. If a pin is to be grounded, it can be bent out slightly or simply trimmed a little bit so that it just touches the copper ground plane for soldering. Often it may be necessary to locate the pads for the middle pins (2, 3, 6, 7) at a slight distance away from the end of the bent pin in order to avoid shorts between the pads. This gap between the end of the pin and the pad can be spanned by the component lead or a short wire and the end of the lead and the pin overlapped 1/16" or so and simply tacked together with a small blob of solder.

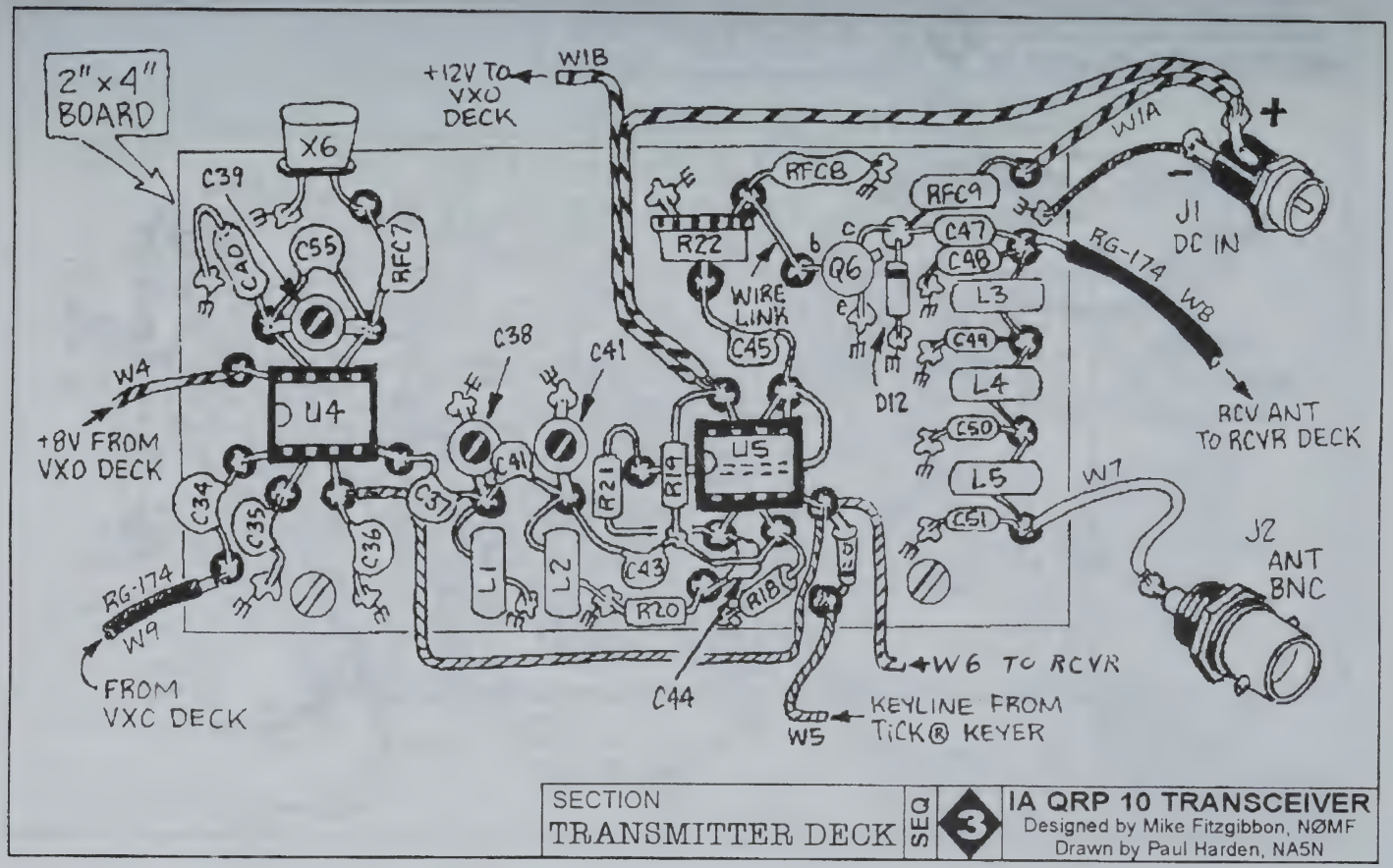
To mount the sockets, after bending the socket pins appropriately, mark the copper groundplane with a pencil dot for each pad location. Place or hold the socket at the intended location and make a mark at the end of each now-bent mounting pin. If one or more of the pins is removed, you can use its next door neighbor as a mounting pin for that side/end of the socket. This is what is done with the LT1252 driver chip in the transmitter. Pins 1, 5, and 8 are unused, so they are trimmed off. Pins 2, 3, 4, 6, and 7 are all then used as mounting pins (see layout)...there is enough room to get pads under all the ends of the pins in this case without a risk of shorting. It takes a little bit of care to do this, but once you get the hang of it, laying down pads and mounting the parts will go quickly and easily.

RECEIVER BOARD

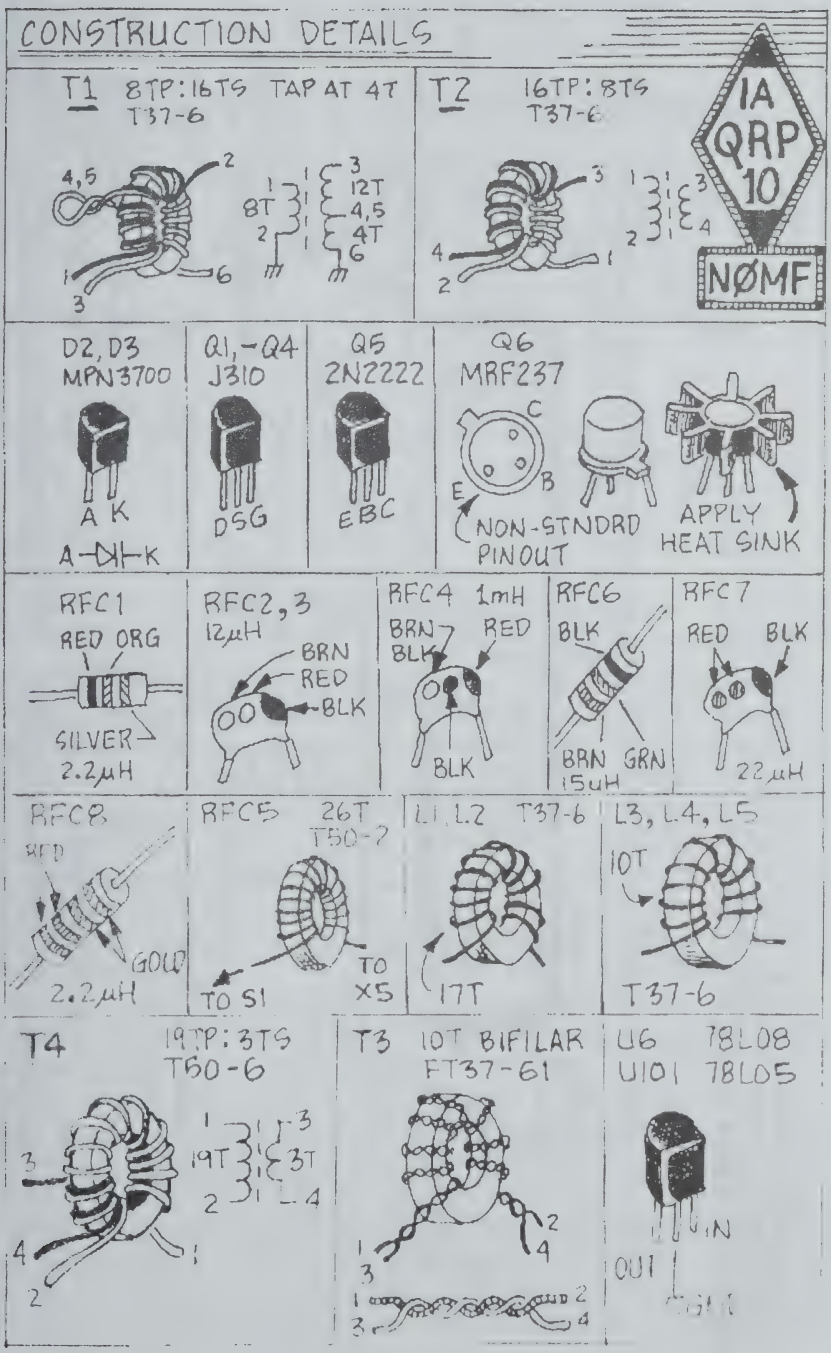
First, a little bit about crystal procurement and matching. These crystals are ordinary inexpensive microprocessor crystals. Buy a lot of at least 10. From the last set of 20 purchased from Digi-Key it was possible to match up five sets of three...enough to build five filters. It is only necessary to match the three crystals for the filter closely, within a spread of 25 hertz or less. The BFO and transmit mixer crystals X4 and X6 can oscillate a bit further from the filter crystals and work just fine since they are "bent" by their tuned circuits. If these crystals are within 40 or 50 hertz of the center of the filter crystals there should be no problem. Of course, it is best to get a group as closely matched as possible, but again, it is only necessary to find three closely matched ones for the receiver filter. When you match them, let

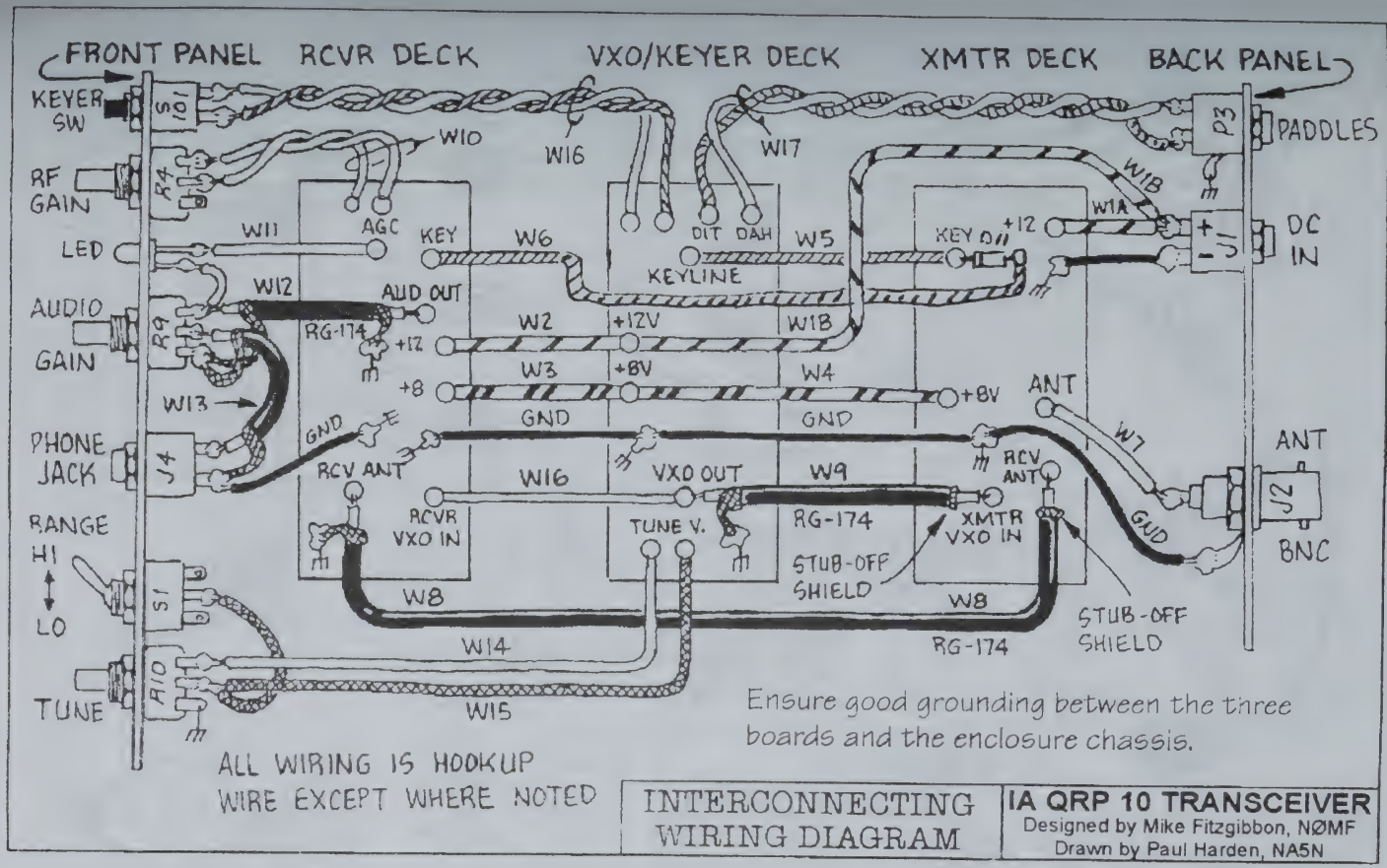

2"x4" BOARD
+8V FROM VXO DECK
W3
FROM VXO DECK
W6
KEY LINE
D4
W10
R4 RF GAIN
D1
C5
C7
C8
W8 RG-174
SHIELD
FROM XMTR
D2
W2
+8V
VXO FROM VXO DECK
W16
W11
D6 LED
AGC
+12V
+12V FROM VXO DECK
R9 AF GAIN
J3 PHONES
Indicates soldered to 2"x4" copper clad board (GND connection)
W12 RG-174 OR TWISTED PAIR
"Round style" pads (punched from copper clad) and glued to 2"x4" board
SECTION
RECEIVE DECK
SEQ
1
IA QRP 10 TRANSCEIVER
Designed by Mike Fitzgibbon, NØMF
Drawn by Paul Harden, NA5N


VXO TO RCVR
W16
VXO TO XMTR DECK
RG-174
W9
SHIELD
+8V TO XMTR DECK
W4
U6
C12
W18
+12V TO J1
2" x 4" BOARD
TUNE
WIPER
R10 IDT POT
GND
T4
T3
R15
R16
Q5
R14
D10
C30
C29
RFC6
C28
R13
R17
C32
D8
R11
W15
RFC5
X5
Q4
HI
SI
LO
D7
W14
+8V TO RCVR
W3
+12V TO RCVR
W2
C11
Q101
FROM PADDLE
DAH DIT
KEYLINE
W5
TO XMTR DECK
R101
C102
U102
C103
OPTIONAL TICK® KEYER SECTION
C101
U101
S101 KEYER
AUDIO PIEZO TRANSDUCER
SECTION
VXO/KEYER DECK
SEQ
2
IA QRP 10 TRANSCEIVER
Designed by Mike Fitzgibbon, NØMF
Drawn by Paul Harden, NA5N



SECTION	SEQ	IA QRP 10 TRANSCEIVER
TRANSMITTER DECK	3	Designed by Mike Fitzgibbon, NØMF Drawn by Paul Harden, NA5N


CONSTRUCTION DETAILS
T1 8TP:16TS TAP AT 4T
T37-6
4,5
2
1
6
3
1
8T
2
1
3
12T
4,5
4T
6
T2 16TP:8TS
T37-6
3
4
2
1
1
3
2
3
4
1A
QRP
10
NØMF
D2, D3
MPN3700
A K
A-|>|-K
Q1,-Q4
J310
DSG
Q5
2N2222
EBC
Q6
MRF237
C
E
B
NON-STNDRD
PINOUT
APPLY
HEAT SINK
RFC1
RED ORG
SILVER
2.2µH
RFC2,3
12µH
BRN
RED
BLK
RFC4 1mH
BRN
BLK
RED
BLK
RFC6
BLK
BRN GRN
15µH
RFC7
RED
BLK
22µH
RFC8
RED
GOLD
2.2µH
RFC5 26T
T50-7
TO S1
TO X5
L1, L2 T37-6
17T
L3, L4, L5
10T
T37-6
T4 19TP:3TS
T50-6
1
19T
2
3
3T
4
3
4
2
1
T3 10T BIFILAR
FT37-61
1
3
2
4
U6 78L08
U101 78L05
IN
OUT
GND

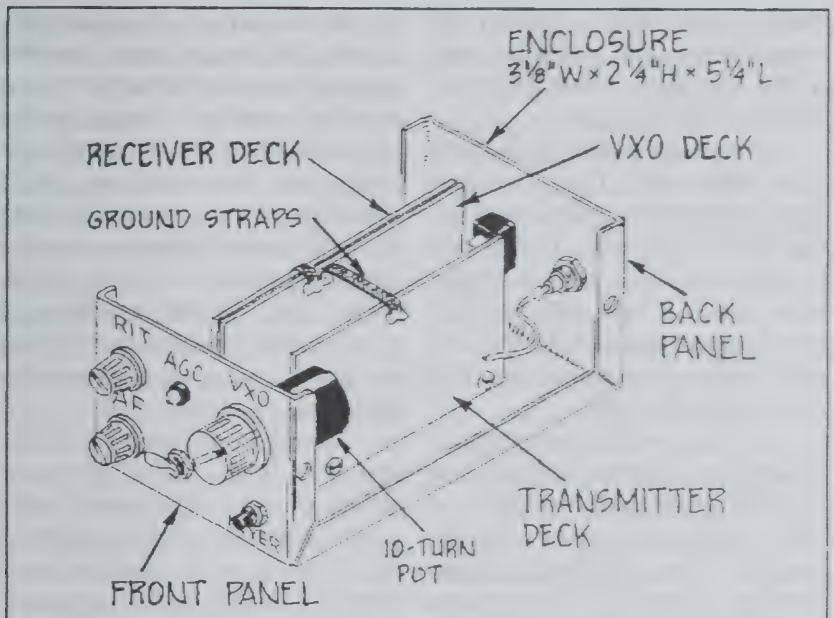


Ensure good grounding between the three boards and the enclosure chassis.

ALL WIRING IS HOOKUP WIRE EXCEPT WHERE NOTED

INTERCONNECTING WIRING DIAGRAM

IA QRP 10 TRANSCEIVER
Designed by Mike Fitzgibbon, NØMF
Drawn by Paul Harden, NA5N



Overall arrangement and Nomenclature

each crystal stablize for a minute or so in the oscillator before you record the frequency. They are very temperature sensitive and just the heat of you finger will send them floating off. You can mark the last three digits of the resonant frequency with a fine-tipped laundry marker on the crystal can to make it easy.

I have purchased several such lots of crystals from both Digi-Key and Mouser and have never been disappointed. You may not be able to use all of the crystals, but you will most likely get several that are closely matched. It seems that if they come out of the same "box", the probability that they will be close in resonant frequency is fairly high. Also, the likelihood that these crystals tend to be a close match is no doubt a function of their relatively low frequency.

Match the crystals using an oscillator (as suggested above) and frequency counter. It also may be possible to match them "by ear" using a receiver to listen to the oscillator signal by using some type of stable audio reference signal to compare the receiver audio against, such as the CW spotting tone of a transceiver... IF the transceiver's tuning is fine enough (and has a digital display with enough resolution) AND your ear is good enough. Another thing that is not a bad idea (but certainly not necessary) is to use a scope to check out each crystal's vigor as you are marking

them for frequency. Once I did have one crystal in a filter that was a little less active, and it did noticeably effect the gain.

The preamp circuit is fairly straightforward. The input and output transformers are wound using # 28 or 30 wire. I often mix smaller wire sizes a bit on these size cores if I have different colors to make it easier to ID the wire ends. You can certainly use both 28 and 30 wire here.

The tap on the secondary of T1 can be made by first winding 12 turns (pass wire through hole 12 times) on the core in either direction. The end for the tap is then trimmed to about 1.5 inches and is striped of enamel and tined with solder right up to the core. A second piece of wire is stripped/tinned a corresponding 1.5inch length and it is twisted together with the now-tinned length from the 12 turn winding coming off the core. Twist these two wires together right up to the core and run the soldering iron down them again to tin/solder them together. The second now-attached wire then continues the winding in the same direction for another 4 turns. There are other ways to make this tap, but this is a good procedure for someone new to this particular task. You have just wound a 16-turn winding with a tap at twelve (or four) turns. The primary winding for this transformer is then wound, *in the same direction*, starting at the end of the secondary nearest the tap, and laid, one-for-one, between the turns of the secondary winding for its eight turns. See the winding pictorial for further toroid winding details. Notice in the schematic that both the eight-turn input and the eight-turn output windings of the preamp on both torroids are laid starting over the grounded ends of the 16-turn windings. Doug, W1FB, always said to wind them like this to minimize capacitive coupling between the windings...so I always do...

Mount the preamp's FET using short leads. Although this is pretty much a fool-proof design (and tested as such by yours truly) it is simply good construction practice to do so in any kind of amplifier. This helps prevent unwanted parasitic oscillations and feedback. A 2N4416 FET can also be used in place of the J310. The 2N4416's case lead should be grounded in addition to the gate.

It is also a good idea to ground the end of trimmer C3 in the input circuit that is connected to the trimmer's adjustment screw to avoid hand/tool capacitance effects when adjusting it, and in all cases where one side of the trimmer is grounded. In the type of trimmers used here this is usually the lead on the rounded end, but can be easily determined by simply measuring the resistance between each lead and the screw itself. It makes no difference with the output circuit trimmer C5 since neither end is grounded. It will be more sensitive to touch, of course, and a non-metallic tool is best

used for adjustment.

After the preamp is built add U1's socket and its associated components. When running the wires to the RF input pot R4 keep the leads as short as possible to avoid picking up unwanted signals. This is the reason that R4 is mounted very close to U1. Be sure to ground the cases of the crystals in the filter to help prevent filter blow-by. Also, just any old LED will not work the best for the "AGC signal-leveling device". You should use one of the LED types suggested in the parts list, or one of identical specs. J305 FETs will also work nicely as the mute switches in the audio line (Q2 & Q3) instead of the J310s if you have an over-abundance of them. Also, one side of the "sidetone level" potentiometer, R7, is left floating. You can mount that leg on a pad all by its lonesome self... And, unlike the *SST*, the audio output of this radio is not fed through both sides of the headphones in series. You *may* do that by floating the ground of the headphone jack (mount the jack in an insulator) and wiring up to the tip and band connections of the jack, but personally I don't care for the out-of-phase-sound that it produces. If your LM386 howls because of insufficient loading due to low-impedence headphones and you don't want to connect the headphone elements in series by floating the ground, try adding a 1 uF non-polarized cap across the phone jack.

After the receiver board is built, mount it and the VXO/doubler board in the enclosure and test it. You can use a short piece of insulated wire to run the VXO signal around the end of the boards and attach it to C9A's pad. RG-174 is used to carry the audio signal both to and from R9, the audio gain pot.

At this time any adjustments to the tuning range (adjust the number of turns/spacing on RFC5) may be made and you can determine the tuning range using a calibrated transceiver by transmitting into a dummy load at low power. Clip a short (two-foot) receiving wire on the input of the preamp. Peak the trimmers in the preamp and receiver with a non-metalic tool for maximum signal and adjust C17, the BFO trimmer, for a nice mellow-sounding tone of your favorite pitch. If you do not get two distinct peaks while turning the trimmers through 360 degrees you probably need to add or subtract inductance in that particular tuned circuit. This means that you are either peaking on the minimum or maximum capacitance of the trimmer and not at the desired peak of resonance, which should be somewhere between the maximum and minimum capacitance. That is, when you turn a trimmer through its range there are two settings which will produce the same overlap of the trimmer's plates and hence the same capacitance. If this doesn't happen, start by spreading or compressing the

turns on the inductor if possible, and if that doesn't work, add or remove turns or change the value slightly until you get two distinct peaks. You can then attach the input to an antenna and peak the trimmers again on some far-distant signals, while admiring the fruit of your work.

TRANSMITTER BOARD

You are now ready for the final phase of the project. First, a little run-down on what is going on here. The 32 mHz VXO signal is fed into mixer/oscillator U4 and combined with the signal generated by the 3.932 mHz local oscillator contained in the chip. The difference, your soon-to-be 28 mHz signal, then passes through a double-tuned bandpass filter (C38, L1, C41, C42, L2) to clean it up a bit, and is then amplified by U5, which also acts as a buffer. The signal is then routed through the drive level control R22 to Q4, the final output transistor. Here the signal is amplified and sent through the low-pass output filter where the harmonics/spurs are removed. Nothing very complicated ... but it seems to work well.

The transmitter is built on a slightly smaller 3.5 inch board. A short piece of RG174 brings the VXO signal to the transmitter board. You only need to ground one (either) end of this coax. Mount the mixer U4 and the buffer/driver U5 just as you have done with the receiver/keyer chips. One new technique is used to make a connection around U5. Run a piece of resistor lead *under* the socket between the pad that is connected to the 620 ohm resistor R21 (actually two resistors in series...a 510 + 120 ohm pair here...close enough) and the number six IC pin. This is one of those places where the hemostats will come in very handy.

The final transistor, a MRF237, has a unique pinout...that is, its collector and emitter leads are *REVERSED*...if you do not want to kiss it goodbye, be sure you observe this. This device will yield an output of 1.5 to 2 watts or so, depending on your supply voltage and characteristics of the transistor. Also, a NTE 341 is listed as a substitute for the MRF237 and is available from Mouser although I have not tried one. Alternatively, a 2SC799 can also be used (reverse collector and emmiter from pictorial) and it will yield about half the output (3/4 W.) of the 237, but it is several bucks less than the 237. The current price of the 237 at RF Parts is about $10, not including shipping, $25 minimum for order. At full output the MRF237 will get quite warm, so a snug healthy-sized heatsink is a necessity, and a little heatsink compound between the transistor case and the heatsink is a probably a worthwhile addition. Simply smear a small bead evenly around the inside of the sink at the bottom edge and let the transistor case spread it out as it is pushed into the heatsink.

Once you have the transmitter board done and the ICs installed, mount it in the box and finish the wiring. Mini-coax is again used to carry the signal from the transmitter's output filter to the preamp input. I also used a bit of desoldering braid to act as ground straps between the boards... otherwise the only good grounding the boards have is through the mounting brackets.

The big moment is at hand! Attach a QRP-level power meter (RF probe or scope will also suffice) and dummy load to the output and set the drive trimmer R22 against the stop to maximum (minimum resistance). Key the rig and adjust trimmers C38 and C42 for maximum output. If you can't get any output, turn R22 fully the opposite way and try again. If no output is still observed go back with your scope or an RF probe and look for the signal along its intended path. Check to see you have a 32mHz signal at the input to U4, then check to see if the local oscillator is running by checking for oscillation of the 3.932 crystal. This oscillator can be heard, along with the BFO (which you should disable first by lifting the lead to pin 8 of U1) on a receiver set for 3.932 mHz if you place the antenna wire close to the circuit. If all is well so far, then check for the signal output at pin 4 of U4 and so on through the transmitter circuit until you find the "interruption".

Using a second well-aligned 10 meter transceiver as a frequency standard and test set-up, key the QRP 10 and adjust C39 to the correct offset. First, set up the test transceiver with a dummy load at 28.060 and attach a short pick-up wire to the QRP 10's antenna connector just to make sure you will hear the signal. Then transmit (a couple of watts will be plenty) with this second "test" rig into the dummy load and tune for the signal on the QRP 10. Now, without moving the tuning knobs on either transceiver, switch the dummy load to the QRP 10 and key it to transmit while adjusting the offset trimmer C39 until the signal from your magnificent creation is at a working pitch in the test transceiver. You may need to add a short receiving wire to the bigger transceiver if you cannot hear the QRP's signal. If you cannot adjust C39 to the correct pitch (due to crystal X6 being a little bit removed from the IF frequency) you may have to adjust the value of C55 slightly upward a bit, try a 39 or 51pF cap. This is no big deal and is very easy to do, but be sure to use a temperature-stable NPO type here. Yup, that NORCAL cap kit sure comes in handy about now...

Once the transmitter is blazing lightning bolts into your dummy load, adjust R7 for a comfortable sidetone level and re-peak the trimmers in the preamp and receiver (except for C17, the BFO) on a weak signal if you have not done so already. You should now have a fully-functioning 10 meter

transceiver. If not, and if you have tested most of your components before installation, you should look for incorrect parts placement/wiring errors by checking things against the pictorial diagrams.

One final note on operating. All SSTs require a fairly efficient set of headphones to produce good volume. The Radio Shack model Nova 43 headphones work OK if you can find some, as well as some others. I have also heard from several sources that the Sony brand of "earbuds" are also quite sensitive, in addition to some of Sony's over/on-the-ear stereophones. Often the sensitivity is listed on the outside of the package. If you still require more audio gain to run a speaker or a set of inefficient stereophones, add a small audio amp to the output. I installed a second LM386 audio amp in the prototype unit on a small board and it powers a large speaker very well without adding too much more to the current consumption. Of course, one could always use a sub-mini DPDT switch to bypass the extra audio amp and cut off the current to it if extremely low current consumption is of particular concern. A good design for such an amplifier can be found in the circuit catalog section of the ARRL's "Data Book", page 8-4.

Lastly, I would like to thank Dave Fifield, AD6A, for his kind help with this project. Dave took the time to clean up the transmitter output and suggested a couple of other needed circuit changes. Also, I would like to thank Doug Hendricks for his fine job with the schematic (ALL Doug's baby) and his generous assistance and encouragement. A special thanks also goes to Paul Harden, NA5N, for his masterful and obviously time-consuming illustrations. I'm sure you will agree that Paul's electronic artwork adds tremendously not only to the ease of construction, but also to the overall quality of the article. It is much appreciated...I could have not done it without these three "pillars" of the QRP community. Their help was simply invaluable. Have fun!
72, Mike, N0MF

IA QRP 10 PARTS LIST

Please see legend below for suppliers

CAPIACITORS

All caps NPO ceramic disc or monolithic 50 V unless noted otherwise

C41	2.2 pF
C1, C8, C34, C37, C43	5 pF
C55	27 pF
C9A	56 pF
C48, C51	82 pF
C10, C16, C28, C29	100 pF
C49, C50	220 pF

C13, C14, C18, C40	270 pF		
C44	820 pF		
C9, C11, C30, C31, C32, C35	.01 uF	20 % ceramic disc	50 V
C23, C24, C36, C45, C46, C47	.022 uF	20 % ceramic disc	50 V
C2, C4, C6, C19, C20, C21	.1 uF	20 % ceramic disc	50 V
C22, C26	2.2 uF	radial electrolytic	25 V
C12, C25, C27	100 uF	radial electrolytic	25 V
C15	470 uF	radial electrolytic	10 V

C33 2-20 pF ceramic trimmer (DK, SG20015-ND; M, 242-4221)

C3, C5, C7, C17, C38, C39, C42 5-50 pF ceramic trimmer (DK, SG50015-ND: M, 242-9850)

RESISTORS

all resistors 5%, 1/8 W carbon film (RS assortment) unless noted otherwise

R2	15 ohm
R17	47 ohm
R3, R16	100 ohm
R20	120 ohm
R1	220 ohm
R13	330 ohm
R15	470 ohm
R21	620 ohm
R6	1k ohm
R8	1.8k ohm
R14	6.8k ohm
R18, R19	10k ohm
R11, R12	100k ohm
R5	2.2 M ohm

R22 100 ohm side-adjust trimmer (RS, 900-5918)

R7 5 M ohm side-adjust trimmer (RS, 900-5932)

R4 5k ohm 1 turn miniature potentiometer (M, 313-1000-5K)

R9 1k ohm 1 turn miniature potentiometer (M, 313-1000-1K)

R10 10k ohm 3 turn potentiometer (A, 970-1830)

INDUCTORS

L1, L2	17 T (turns) T37-6 (RS, 900-7010)
L3, L5	10 T T37-6
L4	11 T T37-6
T1	8 T primary, 16 T secondary, tap secondary at 4 turns up from grounded end, T37-6
T2	16 T primary, 8T secondary T37-6
T3	10 T bifilar FT37-61 (RS, 900-6989)
T4	19 T primary, 3 T secondary T50-6 (RS, 900- 7017)
RFC1, RFC8	2.2 uH molded choke
RFC2, RFC3	12 uH molded choke
RFC4	1mH molded choke
RFC5	26 T T50-2 (RS, 900-7015)
RFC6	15 uH molded choke
RFC7	22 uH molded choke
RFC9	8 T #24 FT37-43 (RS, 900-6988)

SEMICONDUCTORS/ICs

D1, D4, D5, D9, D10	1N4148 silicon diode
D2, D3	MPN3700 PIN diode (A, MPN3700)
D6	hi-eff., 2.1Vf LED (M, 512-MV67539.MP10)
D7	MV209 tuning diode (A, MV209; RS, 900-5698)
D8	MVAM108 tuning diode, note: substitute part 1SV149 available from Doug Hendricks for $2 postpaid—see address below
D11	1N5817 shottky diode (A, 1N5817; DK 1N5817GICT-ND)
D12	1N4755A zener diode
U1, U2, U4	NE602AN DIP mixer/osc (RS, 900-7085)
U3	LM386 audio amp (RS, 276-1731)
U5	video amp (DK, LT1252CN8-ND)
U6	78L08 8V regulator, TO-92 package
Q1, Q2, Q3, Q4	J310 FET (RS, 900-5493)
Q5	2N2222A NPN
Q6	MRF237 NPN (RF)

MISC.

S1	DPDT minature toggle switch
X1-X4, X6	3.932 mHz crystals (DK, X013-ND)
X5	16.00 mHz crystal (DK, X143-ND)

Bud minibox, 5.25 x 3.00 x 2.13 inch (M, 563-CU-3006A)
right-angle brackets, steel, 4-40 threaded, 4 pcs. (M, 534-621)

small knobs, AF & RF gain (M, 450-2034)
large knob, tuning (M, 450-2036)
8-pin machined-pin IC sockets, 6pcs. (RS, RSU11354180; M, 575-199308)
TO-5 heatsink, heavy-duty (DK, HS101-ND)
BNC connector, female (M, 161-9323)
3.5 mm 3-conductor "stereo" jacks (2 pcs)
power connector (M, 163-4305)
power cord with plug (M, 172-4201)

KEYER
TICK keyer IC (ER)
2N2222 NPN
1 uF electrolytic, 25 V, (2 pcs.)
SPST momentary push switch (RS, 275-1571)
78L05 5V regulator, TO-92 package
4.7K 1/8 W resistor
machined-pin IC socket, 8-pin — see QRP 10 misc. parts
piezo transducer (M, 539-PT2060W)

SUPPLIERS
A Allied Electronics, 800 433-5700, www.alliedelec.com
DK Digi-Key, 800 344-4539, www.digikey.com
ER Embedded Research, Box 92492, Rochester NY, 14692, www.frontiernet.net/~embres/
M Mouser Electronics, 800 346-6873, www.mouser.com
RF RF Parts, 800 737-2787, www.rfparts.com
RS Radio Shack, order locally, 800 the-shack, www.radioshack.com/
sheet-metal punch Harbor Freight, 37405-OVGA, 800 905-5220, www.harborfreight.com
Doug Hendricks, 862 Frank Ave., Dos Palos, CA 93620

A MOSFET QRP GALLON

By Wayne McFee NB6M

Want an easy to build QRP Gallon Power Amplifier to use in conjunction with an existing 1 – 1.5 Watt transmitter? This amplifier formed the basis for the 5 Watt Mod for the SMK-1. It features the cheap, readily available, Radio Shack IFR510 Mosfet and can be built into a nice small package and used as an outboard PA, or, with appropriate QSK circuitry, can be built right into a rig.

Given the cost and scarcity of RF transistors these days, and wanting a 5 Watt RF amplifier that could be built either as an outboard amp or as a new PA for an existing rig, I was attracted to the IFR510 because of the successful use of this switching Mosfet in the 5 Watt Mod for the very popular 38 Special, a 30 meter NorCal QRP Club Transceiver Kit.

I was aware of the biasing problems that had been encountered in the 38 Special mod, and knew that I could avoid them by using an adjustable biasing circuit. However, I wanted to avoid both the added complexity of the bias circuit and the necessity of having to adjust it in the first place.

What I wanted was a gate circuit that would leave the Mosfet turned off until driven, provide good driving voltage to the transistor, and provide over-voltage protection for the gate itself.

I found exactly what I was looking for in a circuit developed by Michael Masterson, KA2HZA, and described in his December, 1986 QST article, "Three Fine Mice - MOusFET CW Transmitters".

Using this gate circuit provides gate protection via the zener diode, good drive to the gate of the Mosfet, no biasing circuit is needed, and the mosfet remains cut off until it receives driving voltage.

[See KA2HZA's article for further explanation.]

Although Michael's transmitters were designed to get 12 or more watts out of a single IRF510 switching Mosfet with a 12 volt power supply, simply changing the output filter design values would give me the 5 Watt power level I was looking for. I found that less than a half watt of RF drive delivered to the gate circuit gives a full five watts out with the network values specified in Table 1. So far, I have tested the amp on 40 Meters and on 10 Meters. The 10 Meter amp gives 4.8 watts out with less than a half watt of drive.

In order to use the amplifier outboard of existing 1 - 1.5 Watt QRP transceivers, I decided to use a 3 DB resistive attenuator pad at the input of the amplifier to both reduce the drive level to the gate circuit and, even more importantly, provide a constant, non-reactive 50 Ohm load to the driving transmitter.

In order to keep it simple, a Double Pole, Double Throw toggle switch is used as a T/R switch to bypass the Power Amplifier completely on receive and for those times when the 1 Watt power level of the driving transmitter is sufficient or desired.

The Power Amplifier circuit is shown in Figure 1. The Output Filter Network Values for 5 Watts from 80 to 10 Meters are in Table 1.

As stated above, I have built and tested the circuit for 40 and 10 Meters so far. Indications are that the 10 Meter values would work on 12 Meters as well, but fur-

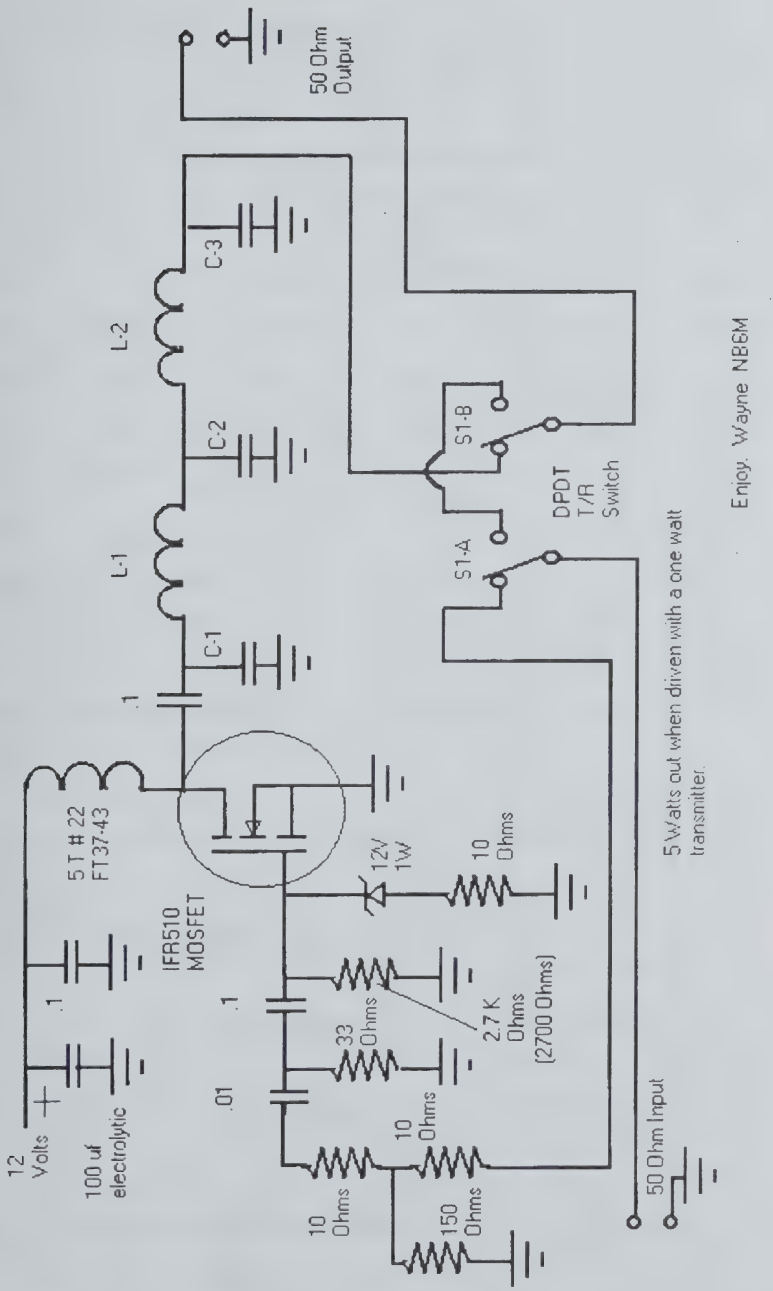

12 Volts
100 uf electrolytic
.1
5 T # 22 FT37-43
IFR510 MOSFET
.1
.01
.1
33 Ohms
2.7 K Ohms (2700 Ohms)
12V 1W
10 Ohms
10 Ohms
10 Ohms
150 Ohms
C-1
L-1
C-2
L-2
C-3
50 Ohm Output
S1-B
S1-A
DPDT T/R Switch
50 Ohm Input
5 Watts out when driven with a one watt transmitter.
Enjoy. Wayne NB&M

Fig. 1

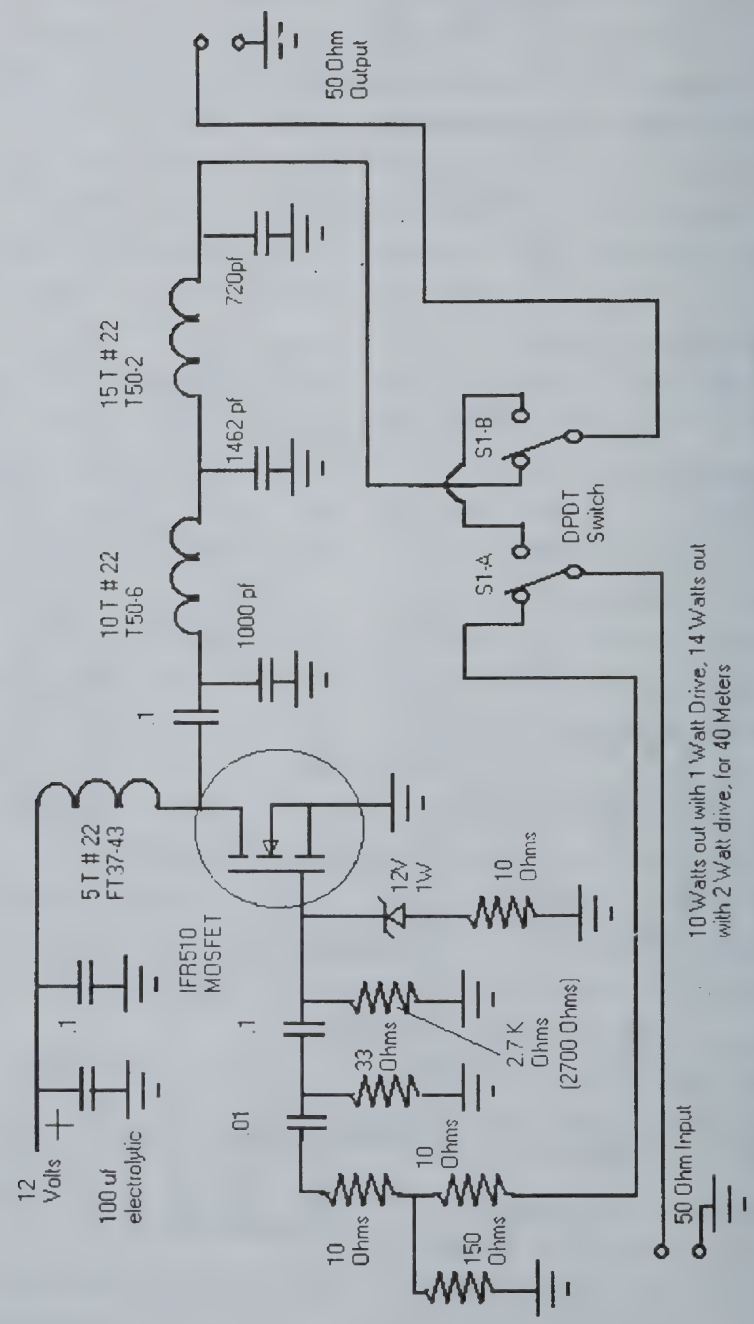

12 Volts
100 uf electrolytic
.1
5 T # 22 FT37-43
IFR510 MOSFET
.01
.1
33 Ohms
2.7 K Ohms (2700 Ohms)
12V 1W
10 Ohms
10 Ohms
10 Ohms
150 Ohms
.1
10 T # 22 T50-6
1000 pf
1462 pf
15 T # 22 T50-2
720pf
50 Ohm Output
S1-A
S1-B
DPDT Switch
50 Ohm Input
10 Watts out with 1 Watt Drive, 14 Watts out with 2 Watt drive, for 40 Meters
Enjoy, Wayne NB6M

Fig. 2

Table 1. Output Network Component Values

	C-1	L-1	C-2	L-2	C-3
80 Meters	820 pf	21 T # 24 T50-2	1600 pf	25 T # 24 T50-2	910 pf
40 Meters	390 pf	16 T # 24 T37-2	820 pf	19 T # 24 T37-2	470 pf
30 Meters	270 pf	13 T # 24 T37-2	560 pf	16 T # 24 T37-2	330 pf
20 Meters	220 pf	11 T # 24 T37-2	390 pf	13 T # 24 T37-2	240 pf
17 Meters	180 pf	10 T # 24 T37-2	330 pf	14 T # 24 T37-6	180 pf
15 Meters	150 pf	9 T # 24 T37-2	270 pf	11 T # 24 T37-2	150 pf
12 Meters	135 pf	10 T # 24 T37-6	230 pf	10 T # 24 T37-2	135 pf
10 Meters	120 pf	9 T # 24 T37-6	220 pr	11 T # 24 T37-6	120 pf

ther testing is necessary. A multi-band Power Amplifier module could easily be constructed using a rotary or other type of switch to select the appropriate output network for the band of operation desired.

An RF sensing relay circuit could easily be used to switch the amplifier in and out of the circuit automatically. One example of such a circuit is described in the March, 1999, QST article "A Broadband HF Amplifier Using Low-Cost Mosfets", by Mike Kossor, WA2EBY.

Should you desire more power output from the amplifier, twelve or more watts of output can be had by using the output filter network values published in Michael Masterson's original article.

I have built and tested this power amplifier on 40 meters using the output filter values shown in Figure 2, which resulted in a power output of ten watts with a 1 Watt input, and fourteen watts out with 2 Watts of input. For these tests, the amplifier was being supplied from a 13.8 Volts DC power supply.

This project lends itself particularly well to "Ugly Style" construction. There are a small number of parts involved and there is a ready availability of parts going to ground throughout the circuit, which make natural stand-offs for the others. Should you prefer, it can easily be built "Manhattan" style, or on perfboard, or you can etch a circuit board for it. The circuit is simple and un-complicated, and it should be easy to lay out with whichever method you choose. The main thing to remember is to keep all leads short.

The Mosfet will need a heat sink, and can be mounted on the side or rear of the case for heat sinking purposes if a single-sided

PC Board or metal enclosure is used. If a non-metallic enclosure is used, a TO-220 style heat sink will do nicely. The higher power version may need a little larger heat sink, although my tests indicate that the TO-220 style heat sink is enough for that version as well. In either case, the Drain of the Mosfet will need to be insulated from ground.

Whether you choose to build this RF Power Amplifier as an outboard amp, or as part of a transmitter, either at the QRP Gallon level or "almost QRO", you will be well satisfied with the results. Enjoy. Wayne, NB6M

Portable, No-Solder, No-Tuner, Resonant Twinlead 20M Dipole!!

by Rich Wadsworth, KF6QKI
320 Eureka Canyon Rd.
Watsonville, CA 95076

This article describes construction of a portable dipole for 14.060 MHz that is relatively low loss and does not require an antenna tuner. Dipole construction has been written about so much that you might ask "What can Rich say that's new?". Nothing, really, but I haven't seen this particular antenna described, so it's my duty to do it.

My first attempt at a portable dipole was using 20 AWG speaker wire, with the leads simply pulled apart for the length required for a half wave top and the rest used for the feed line. The simplicity of no connections, no tuner, and minimal bulk was compelling! And it worked (I made contacts)! Jim Duffey's antenna presentation at the 1999 PacifiCon QRP Symposium made me rethink that. The loss in the feed line can be substantial, especially at the higher frequencies, if the choice in feed line is not rationally made. Since a dipole's standard height is a half-wave length, I calculated those losses for 33 feet of coaxial feed line at 14 MHz. RG174 will lose about 1.5 dB in 33 feet, RG58 about 0.5 dB, RG8X about 0.4 dB. RG8 is too bulky for portable use, but has about 0.25 dB loss. For comparison, the ARRL Antenna Book shows 18 AWG zip cord (similar to my speaker wire) to have about 3.8 dB loss per 100 feet at 14 MHz, or around 1.3 dB for that 33 feet length. Note that mini-coax or zip cord has about one dB more loss than RG58. Are you willing to give up that much of your QRP power and your hearing ability? I decided to limit antenna losses in my system to a half dB, which means I draw the line at RG58 or equivalent loss.

It is generally accepted that 300 ohm ribbon feeder has much less loss than RG58, though I can't

find it in the ARRL antenna book. Some authors have stated that TV twin lead has similar loss as RG58, which is acceptable to me. A coil of twin-lead is less bulky and lighter than the same length of RG58. These qualities led me to experiment with it. One problem is that its 300 ohm impedance normally requires a tuner or 4:1 balun at the rig end.

But, since I want approximately a half wave length of feed line anyway, I decided to experiment with the concept of making it an exact electrical half-wave long. Any feed line will reflect the impedance of its load at points along the feed line that are multiples of a half wave length. Since a dipole pitched as a flat-top or inverted vee has an impedance of 50 to 70 ohms, a feed line that is an electrical half wave long will also measure 50 to 70 ohms at the transceiver end, eliminating the need for a tuner or 4:1 balun.

To determine the electrical length of a wire, you must adjust for the velocity factor (VF), which is the ratio of the speed of the signal in the wire compared to the speed of light in free space. For twin lead, it is said to be 0.82, meaning that the signal will travel at 0.82 times the speed of light, so it will only go 82% as far in one cycle as one would normally compute using the formula 984/MHz. I put a 50 ohm dummy load on one end of a 49 ft length of twin lead and used an MFJ 259B antenna analyzer to measure the resonant frequency, which was 8.10 MHz. The theoretical 1/2 wave length would be 492/MHz, or 60.7 feet. so the VF is 49/60.7 = 0.81, close to the 0.82 that is published. A 1/2 wave for 14.06 MHz would therefor be 492 x 0.81 / 14.06 or 28.3 feet. I cut a piece that length, soldered a 51 ohm resistor between the leads at one end, and hoisted that end up in the air. I then measured the SWR with the 259B set for 14.060 MHz and found the SWR to be 1:1, and the 2:1 bandwidth to be 7.76 to 8.47 MHz. That would allow the feed line to vary in length between 27.0 and 29.5 feet for a 2:1 maximum SWR, so the length is not too critical.

Now comes the fun part. With another length of twin lead, I cut the web between the wires, creating 17 ft legs, and left 28.3 feet of feed line. I hung it, tested, and trimmed the legs until the 259B measured 1:1 SWR. The leg length turned out to be 16.75 feet. (NOTE: the VF determined above only applies to the feed line portion of the antenna) There is no soldering and no special connections at the antenna feed point. I left the ends of the legs an inch longer to have something to tie to for hanging. I reinforced the antenna end of the uncut twin lead with a nylon pull tie, with another pull tie looped through it to tie a string to it for using as an inverted vee. When hung as an inverted vee at a height of 28 feet, the 1.2:1 SWR bandwidth measured from 14.000 to 14.130 MHz. To con-

nect the feed line to the transceiver, I use a binding post-BNC adaptor that is available from Ocean State.

I used Radio Shack 22 AWG twin lead that was available in 50 ft rolls. I haven't seen it lately, but I'm sure its equivalent is available somewhere. To have no solder connections, you need at least 45 feet. When I cut the twin lead to make the legs, I just cut the "web" down the middle and didn't try to cut it out from between the wires. It helps make the whole thing roll up into a coil, and the legs don't tangle when it's unrolled, since they're a little stiff. This antenna can be scaled up or down for other frequencies also. An even lower loss version can be made with 20 AWG 300 ohm "window" line, though the VF of that line may be different and should be measured before construction.

Wait, you say - "After all that talk about having it a half wave up, you only have it up 28 feet." I carry a 6 ft RG58 jumper to get it higher if the right branch is available. Since impedance at the feed point is 50 to 70 ohms, 50 ohm coax can be used to extend the feed line. I have used it in the field a few times as an inverted vee, at various heights and leg angles, and used an SWR meter to double check its consistency in different situations. SWR never exceeded 1.5:1, so I feel safe leaving the tuner home. For backpacking, I leave the SWR meter home too!

And there's a bonus: As long as you use the balanced feed line (or extend it with balanced line), it CAN be used as a multi-band antenna, with a tuner, from 10 to 40 meters. I quote John Heyes G3BDQ from "Practical Wire Antennas" page 18: "Even when the top of the doublet antenna is a quarter-wavelength long, the antenna will still be an effective radiator." Heyes used an antenna with a 30 ft top length about 25 ft off the ground on 7 MHz and received consistently good reports from all Europe and even the USA (from England). It will not perform as well at 7 MHz as at 14 MHz, however, though 14 through 28 MHz should be excellent.

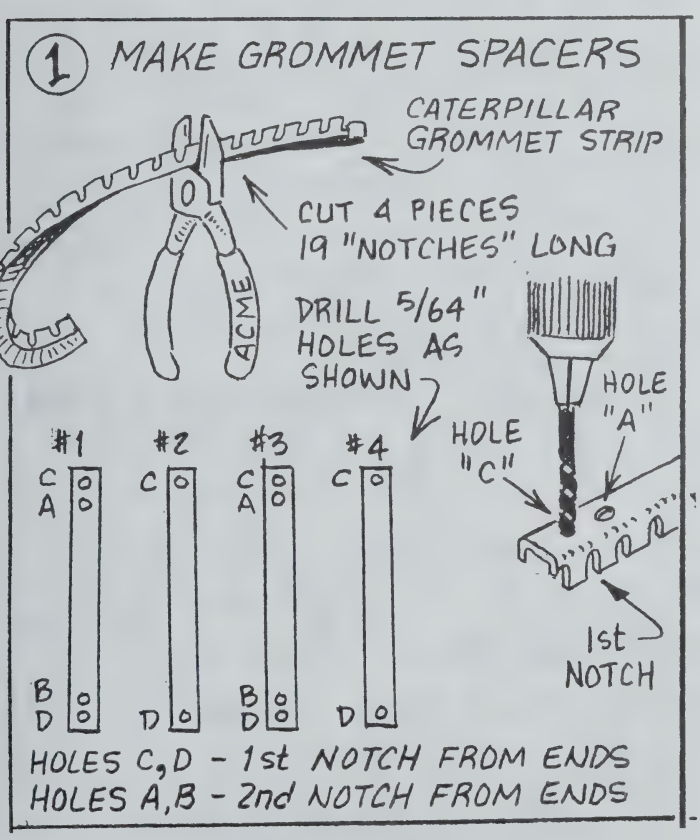
My shack 20 meter antenna is an inverted vee up 26 feet and I've made QRP contacts to New York, Florida and Alaska, and I expect equal or better performance from this one. I think it's a winner.

72, Rich KF6QKI

Building the St. Louis Coil

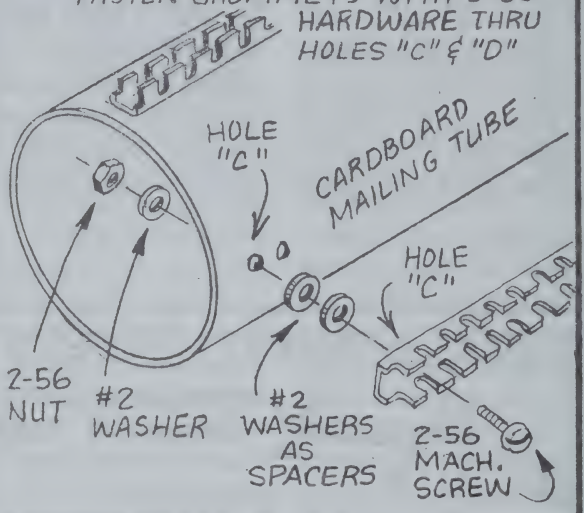
by Andy Becker, W0NVM & Dave Gauding, NF0R
Illustrated by Paul Harden, NA5N

The Spring 00 issue of QRPp featured an article by Andy Becker and Dave Gauding on how to build a vertical antenna that used a large coil. [See Spring 00 QRPp, pp. 3 - 20, St. Louis Pocket Vertical]. Coil stock is very hard to come by these days, so Andy and Dave decided to be true hams, they figured out how to homebrew their own. We had many, many requests for a pictoral description on how to build the coil, so we asked Paul Harden, NA5N to do a series of illustrations on how to build a coil, using Andy and Dave's method. This article is the result. Enjoy. Andy, Dave and Paul.



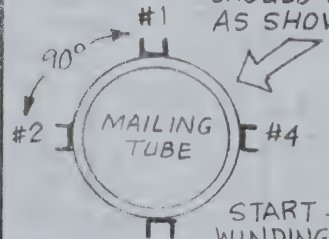
(2) PREPARE WINDING FORM

MOUNT GROMMETS #1–#4 ON A 3¼" MAILING TUBE EVERY 90°. DRILL 5/64" HOLES THRU TUBE WHERE HOLES A,B,C,D OCCUR. FASTEN GROMMETS WITH 2-56 HARDWARE THRU HOLES "C" & "D"

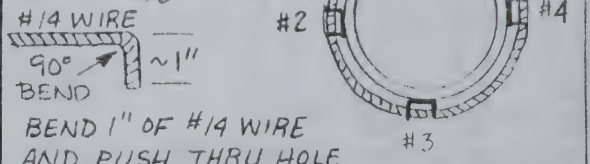


(3) WINDING THE COIL

GROMMETS #1, #2, #3, #4 SHOULD BE MOUNTED AS SHOWN.

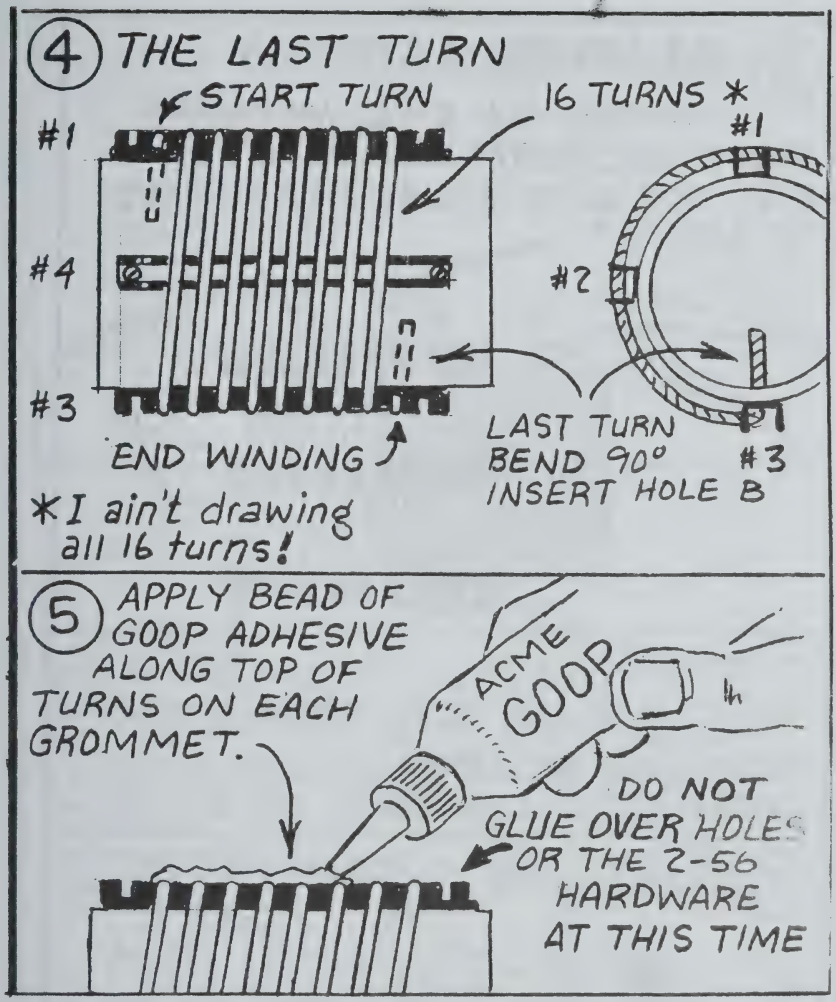


START COIL ON LEFT-HAND END, GROMMET #1



BEND 1" OF #14 WIRE AND PUSH THRU HOLE "A" (2nd NOTCH) ON #1 TO START. WIND CCW. 1st TURN USES 2nd NOTCH ON ALL GROMMETS.

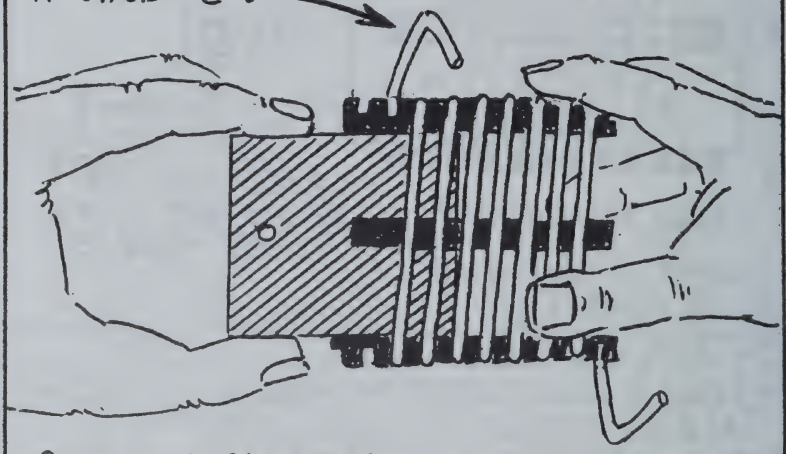
NOTE: 16 TURNS, 3¼" dia. = 14FT. WIRE



AFTER GLUING, EXPOSE TO A 100 WATT LAMP. WARMED ADHESIVE WILL FLOW THRU COIL WIRE FOR SOLID BOND. CURE FOR 24 HOURS.

(6) 24 HOURS LATER...

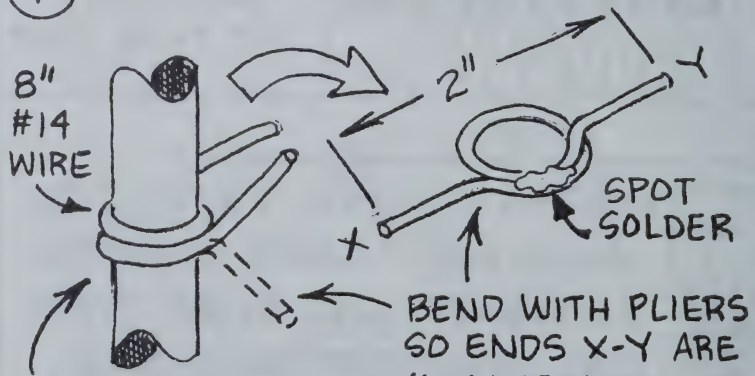
REMOVE ALL 2-56 HARDWARE FROM COIL FORM & GROMMETS. PULL OUT WIRE STUBS FROM HOLES "A" AND "C".



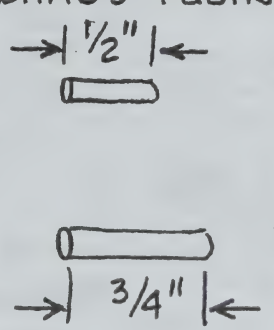
GENTLY SLIDE COIL FROM FORM

BEND WIRE STUBS BACK INTO GROMMET HOLES WHEN DONE

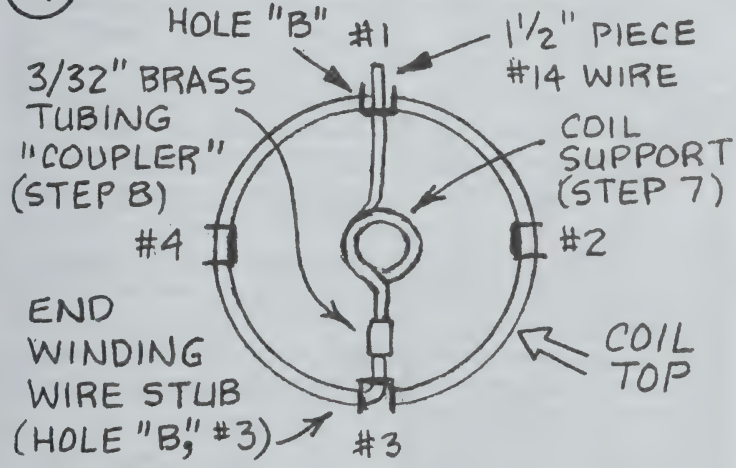
(7) BUILD COIL SUPPORTS (2)



(8) CUT 3/32" DIA. BRASS TUBING INTO PIECE 1/2" LONG AND ONE PIECE 3/4" LONG FOR THE COUPLERS.

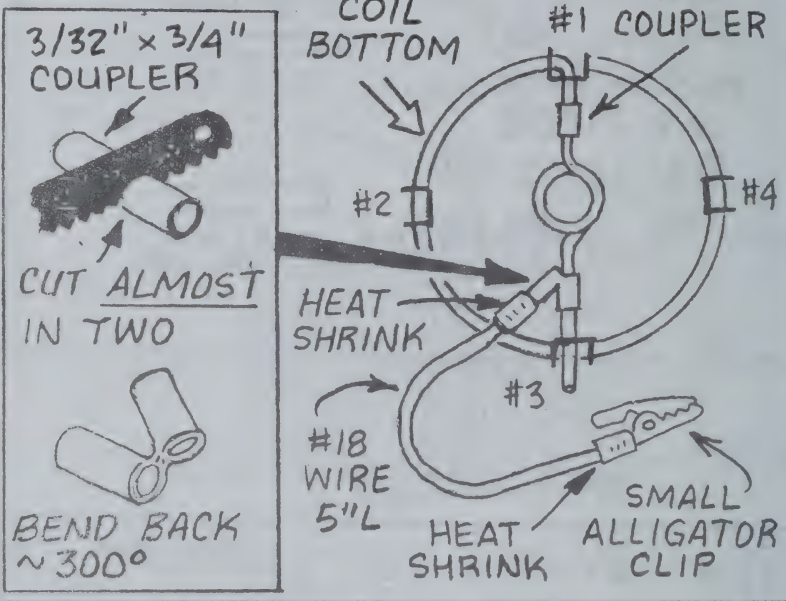


(9) ASSEMBLE TOP SUPPORT



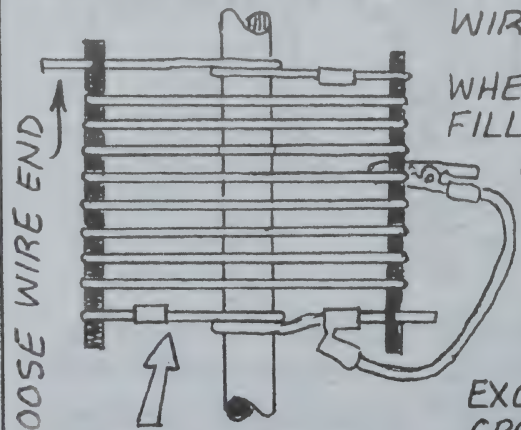
MOUNT TOP COIL SUPPORT TO COIL END WINDING WITH COUPLER, THEN SOLDER. ADD 1 1/2" WIRE PIECE WITH COUPLER AND SOLDER.

(10) BOTTOM SUPPORT



(11) FINISHING TOUCHES

PLACE COIL ON .505" MAST SECTION & CENTER BY MOVING TOP & BOTTOM WITH SLIP FROM LOOSE WIRE ENDS.



WHEN CENTERED, FILL REST OF GROMMETS WITH GOOP ADHESIVE PER STEP 5.

TRIM OFF EXCESS WIRE & GROMMETS IF DESIRED

COIL: 18μH
Q: 300-350

The Spring QueSO Party

by Bob Tellefsen, N6WG

Howdy, neighbor. Come on in and set. Have I got something to tell you!

You know, out in the desert, at the end of Highway 40M, there's that little town called Fortymeters. Nice little place, not as many people as it once had, but still a lot of nice folks there. I was out there about a month ago, and had several nice chats with the locals.

Then I got an invite to what they called an ARCI Spring QSO Party. I figgered it was just misspelled, meaning a Queso Party, and you know how I love cheese. So I headed out there Saturday morning. When I pulled into town, something didn't look right.

This was supposed to be a big deal cheese party, right? Well, where were all the people? The General Store was closed and the lights were out. No one working there that morning. Well, I thought, it's a big deal party, so maybe they took the day off, and I'll see them there. Stuck my head in the Short Branch saloon, but nobody there either. Even the gas station was closed. Noticed there weren't any horses or cars on the street, either.

Gettin' a bit spooky, you know?

Well, I figgered everyone must be at the Queso Party, so started walkin' around, lookin' for it. Didn't have an address, but Fortymeters isn't a big place. Had to be somewhere close by. You know, I spent the whole day Saturday lookin' for that Queso Party and never did find it anywhere in Fortymeters.

I did run into a few other strangers huntin' around for it too, but nobody else had any better luck. We'd stop and chat a few minutes then move on, huntin' for that darned Queso Party. We pretty much decided that Fortymeters had become a ghost town, for the moment, anyway, and the Queso Party was a bust. Sure wonder what happened to it.

Anyway, think I'll run out there again in a while and see if anyone has showed up and any places open again. Maybe I'll find out where everyone went. Just can't figger it out. Sure sorry I missed out on that cheese feed Queso Party.

73, Bob N6WG

An Integrated & Portable PSK31 Station for 80/20 Meters ... Without Using a PC

by George Heron, N2APB
n2apb@amsat.org

PSK31 is the latest communications mode to sweep the interest of hams worldwide. Its inherent ability to dig out low, near-inaudible signals from the spectrum is ideally suited for low power QRP enthusiasts. But today's technology is tied to use of a portable computer, or even to a desktop computer. Thus the PSK operator is locked into a cumbersome and often fixed-location station. But there's hope!

Here I preseht the design and construction of a two-band PSK station utilizing a small and inexpensive DSP controller board coupled with the simple PSK transceiver boards from NN1G and Small Wonder Labs. I detail the techniques used to perform PSK processing in a small form factor, and the techniques used to create a novel and very functional "human interface" using a keyer paddle for input and audio Morse for output ... to create a PSK rig that can be easily taken to the field.

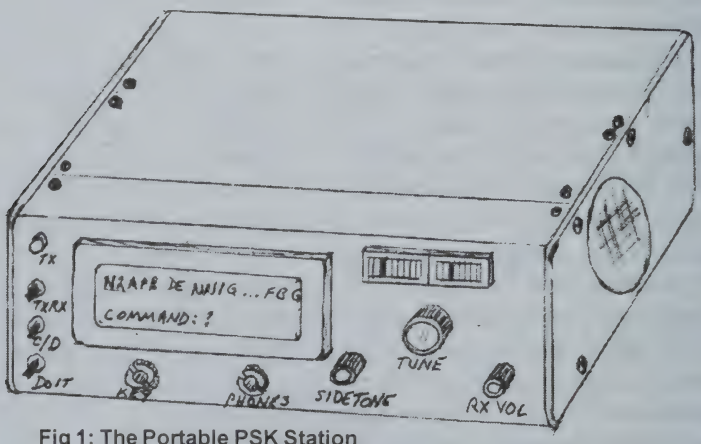


Fig 1: The Portable PSK Station
(Full color photos can be found on the NJQRP website at www.njqrp.org/portablepsk/

I first became interested in PSK31 when it was introduced to us by Peter Martinez, G4PLZ in RSGB's RadCom magazine several years ago. I was able to get on the air with this digital mode using the various components - PC sound card, interface cables, and software developed by the pioneers, and I had a great time making contacts all over the world.

I was later able to more effectively work this mode with the advent of some enabling software

and hardware technology. DigiPan, a PSK31 control program written by Skip Teller, KH6TY/4, has a panoramic graphical display showing all station activity within a specified band segment. What an astonishing improvement in the user interface for PSK31!

Then, around the time of the Pacificon QRP weekend last year, Dave Benson, NN1G designed and started selling the PSK-20, a single board transceiver kit dedicated for PSK3 operation. This board requires no physical tuning of components, and when used in conjunction with DigiPan (or other DSP software) it's audio passband could be analyzed and PSK signals across its 2 KHz window are able to be demodulated and displayed as ASCII text on the PC. What a marvelous improvement to size, stability and cost of a PSK station.

BUT ... even with these clever hardware and software designs, there still is room for improvement. The at-times big and cumbersome PC is still needed for PSK operation due to the spectral analysis and special character encoding requirements of this mode. And even if one were to use a modern laptop, taking these expensive and delicate computers to the field is a hair-raising experience. Plus, have you ever tried viewing the laptop's LCD display in the bright sunlight of a mountaintop QRP field adventure? It's very tough indeed to see the subtle spectral lines or even the data on the screen! And that's only if your laptop's battery lasts long enough to enjoy the joys of PSK'ing out in the open. Sheesh, what's an industrious QRPer to do??

Smaller, Cheaper, Integrated

They say that necessity is the mother of invention, but in this case we have the mother, father, two uncles and 39 cousins upon whose backs this ultimate solution is supported. I'm just the one to bring it all together with some conventional melting of solder, software glue and lots of experimentation along the way. A smile will slowly come to your face as you see how the various pieces of the puzzle came together.

There were **three major challenges**, or design goals as we say in industry:

1) Replace the computing power of the PC with something lighter and less power-hungry;

2) Replace the keyboard and display "input/output" of the PC with something more portable and ham-friendly; and

3) Find a small, trail-friendly, very stable, and inexpensive transceiver design to embed in the PSK station.

DSP Boards to the Rescue

The challenge of finding suitable computing power to replace the PC was actually an easy one. The solution was already present in the form of inexpensive DSP "evaluation boards" provided by the major industry players like Motorola, Analog Devices and

Texas Instruments. These companies produce eval boards to help engineers quickly and easily try out their newer DSP chips - and it just so happens that these single-board DSP computers have tons of horsepower for just about any modem envisioned(PSK, RTTY, PACTOR, etc), audio filters, demodulation schemes, etc. For years, the communications wizards[2] in our ham ranks have been extolling the virtues of using these eval boards for our own purposes.

I selected the Motorola DSP56002EVM eval board as my main PSK modem processor. Johan Forrer KC7WW wrote a fabulous article in the August 1995 issue of QEX explaining how to use this board as a filter and a modem, and TAPR ultimately made a kit out of it for experimenters to play with.

The clincher for my selection of this board is that Peter Martinez, G3PLX, the father of PSK31, actually wrote a version of his PSK modem on this platform. Peter made his source code available for others to use and it explained how the whole system worked! And to top it off, G3PLX also provided the source code for his companion PC program that interfaced to the "EVM56K", thus clearly explaining the significant amount of extra processing required on top of what is done on the DSP board.

Now this need for a companion PC gets us back to the same problem as before, but we'll tackle it next!

The "Human Interface"

In addition to providing additional processing - which I call "spectral processing" - this companion PC also provided the human interface. That is, its keyboard and wide graphic display provides the main way a human "talks" to a computing device. These I/O devices are common to most of us and we've grown accustomed to efficient use of them in everyday business and home life.

But once again stepping onto the shoulders of some uncles and cousins, we QRPers have found another very convenient, and more radio-friendly way to communicate with our complicated radio gear these days ... with Morse code! Yup, this "slow and antiquated mode of communications" comes to the rescue for our advanced technology project.

Okay, here's how we use Morse code for the I/O needs of a complicated piece of radio gear.

Considering that a PSK station controller needs to be provided data **input** by the human, a **standard keyer paddle** can be an elegant solution. Simple Morse code can be used to command the PSK controller as well as to actually send data to the receiving station. What could be simpler or more natural than using a paddle on the trail, or even on the desk at home?! Gary Diana, N2JGU of Embedded Research uses this technique in spades to control his immensely popular TiCK keyer

chip.

Good ol' Morse code comes to the rescue again when we consider the data **output** needs of a PSK31 station controller. Audio annunciation of frequency has been popularized by Dave Benson, NN1G, another uncle-genius in our field who created an audio frequency dial that delivers the current settings of VFOs via Morse code through the audio chain of a radio. This same brilliant technique can be effectively used to convey the rig's state information, buffer contents, mode settings, and (especially) the PSK messages being sent to you by the station with whom you are in communication.

Of course there are some tricks and special sub-challenges to be solved when using Morse code for a digital mode, and we'll describe the solutions in a bit. But what a neat and efficient concept we've introduced: using a paddle as an input, and audio Morse code as output for a digital communications mode! Sort of "anachronistic", as they say in literature.

It's Truly a Small Wonder

The last design goal was solved as easily as falling off a log, but it's so very important to make the brilliance of the solution crystal clear.

It's impractical to take one's multi-thousand dollar YeaComWood transceiver in most kinds of portable or field operation. You need to have a pretty darned stable VFO to operate PSK31, and the little QRP kits these days (and even some of the bigger ones) just don't have the specs to easily accommodate the PSK stability demands. So it's important to use one of the more expensive rigs ... and one doesn't readily pick up one of these for an afternoon jaunt along the Appalachian Trail.

As mentioned a moment ago, Dave Benson, NN1G, developed a super simple, stable, no-controls single board SSB transceiver specifically geared for PSK use. It's wide audio passband allows a 2 KHz band of warbling, 2-tone PSK signals to get through and be presented to software for decoding. And the computer's precise tones can be presented to the linear transmit chain of this board to take care of the transmit half of the job. The PSK-20 board is sold as a kit by NN1G as proprietor of Small Wonder Labs. Dave also designed a simplified version of this initial board to work on 80 meters. He contributed this project to the NJQRP, who are kitting and selling it as the PSK-80 "Warbler".

The heart of using Morse code in these two boards, and other PSK-xx boards to come, serve beautifully as the RF element of the Portable PSK Station ... small, low cost, stable, no controls, perfect presentation of audio signal to a mating computing block. Like I said, brilliant!

Getting Down to Brass Tacks

Okay, so enough of the background, selection logic and heroes upon whose shoulders we stand.

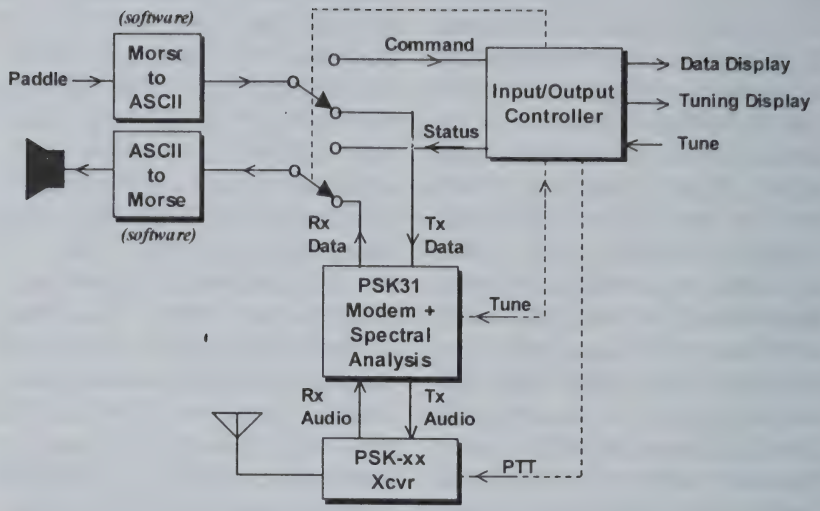


Figure 2: Simplified Block Diagram

Let's next get into the nitty-gritty of this project and describe how it works. Please refer to the Simplified Block Diagram (Fig. 2) as we describe the basic elements and interaction of the Portable PSK Station.

Since it is crucial to understanding the design and implementation, we'll reiterate the three *foundational elements* of this project: (1) use of Morse code for I/O, (2) use of a small computing blocks, and (3) use of the PSK-xx transceiver boards.

The heart of using Morse code in this project is contained in the Morse-to-ASCII, and the ASCII-to-Morse software blocks. "ASCII" is a 7- or 8-bit code that represents all possible "printable" (and non-printable) characters used within a computer system. These characters are often thought of as the "text" in text messages.

The **Morse-to-ASCII** software block is used for taking input from the paddle in the form of a conventional keyer, and then converting the Morse code to an ASCII equivalent character. This ASCII character is either sent to the PSK modem and transceiver board for transmission as part of the communication, or it is sent to the Supervisory Controller and interpreted as a "command." (More on the Supervisory Controller in a moment.)

The **ASCII-to-Morse** software block is used to take either the ASCII "data" character received from the RF link, or the "status" character being generated by the Supervisory Controller and converts it to Morse code. This Morse equivalent of the data or status is

then modulated at a configurable frequency to give a pleasant tone and it's amplified and played out through the rig's speaker (or phones). In this way the operator hears the received signal and the system status as Morse code tones coming from the box.

(Note ... A clever trick is used to help the operator differentiate between data and status audio Morse signals. Data is audibly presented at the link data rate of 31 bps, and at a lower tone of about 600 Hz. Status coming from the Supervisory Controller is audibly played at a higher frequency of 750 Hz and at a faster rate of 25 wpm. These speed and tone setting s are user configurable.)

At this point it's important to describe the **computing blocks** in the system. We've represented these blocks as the PSK-processing block, and the Supervisory Controller block.

As in each of the earlier PSK systems from Martinez, et al, there are two main computing functions required for the processing of PSK data. First, there is the **PSK modem**, which performs the actual modulation/demodulation of data in the form of handling phase reversals within precise timing windows. Second, there is an operation that I've dubbed **Spectral Analysis** that deals with the interpretation and conversion of the raw modem data to extract the data and to provide various information about the signal (phase/frequency, duplex operation, synchronization, etc.). This Spectral Analysis block also typically provided the graphical user interface by indicating the spectrum or some kind of a tuning graphic (e.g., a radar-like circular, vector scope). In this project, we'll take the output of the Spectral Analysis block and use it to drive some other schemes for determining proper tuning.

The other main computing block is called the **Supervisory Controller**, and it performs as a low-level hardware device driver for the various controls and displays in the system. In essence, it is the traffic cop that determines where and how data. commands. and status flow in the system.

The Supervisory Controller also takes raw information from the Spectral Analysis block, processes it and drives a unique, special display device (LED bar graph array) to visually depict the phase condition of the received signal. With this clever display, the operator is able to tune for best reception and see the phase effects of his tuning. This tuning aid is another hidden gem in the design of this project's minimal user interface.

Tuning is accomplished with a shaft encoder on the front panel. An optional (though useful) 2-line LCD display is also on the front panel to optionally display the incoming data or system status.

The last element in the Block Diagram is the **PSK-xx transceiver board(s)**. The boards ac-

cept audio data stream from the Modem block, and present received audio to the Modem and Spectral Analysis block. Push-To-Talk control is provided to the PSK-xx board from the Supervisory Controller board, thus providing an automatic means of switching the transceiver between transmit and receive modes.

So as you can see, in it's simplified form, the Portable PSK system can be viewed as a way of sending data to a modem and transmitter, getting received data back, and displaying to the user the inherent quality or state of the received signal in order that rig can be accurately tuned.

DETAILED SYSTEM DIAGRAM

Now that we have the basics covered, let's take a walk through the detailed representation of this Portable PSK project. We won't repeat the basic data, command and status flow described thus far, but we'll delve into some of the specific implementation approaches. Additionally, we'll focus in on the novel design aspects for tuning, display and control.

(Remember that the previous discussion was an idealized and simplified overview of the system. This section, however, describes the actual hardware and software comprising the Portable PSK project, and some real world trade-offs were necessary in order to achieve the desired results.)

First, let's identify the major elements of this real system. Please refer to Figure 3: Detailed System Diagram for the following discussion.

The **PSK-20 and PSK-80 transceiver boards** are clearly indicated on the right side of figure 3. A DPDT-center-OFF switch located on the rear panel of the unit supplies 12 volt power to the selected board. It also simultaneously takes the RF output from the selected board and routes it to the rear panel SO-239 "ANTENNA" jack. A switch with a center-off position is used in order to have no board selected when not actively using the boards, thus saving battery power.)

The main scheme in using these transceiver boards is that we're providing "n bands of PSK operation". That is, you could use one board or 10 different boards to ultimately provide a very sprectrum-capable PSK station. I would imagine that loading of the parallel-connected audio input and output lines would become an issue when using a greater number of boards, but that's an easy issue to solve.

Alternatively, in order to provide even more flexibility, these common audio input and output lines could be brought out to 1/8" jacks at the rear panel for connection to an external transceiver. Thus the Portable PSK unit becomes a bit less portable, but when coupled with an appropriately-stable transceiver on the bench, you'd be able to reach any frequency in the RF spectrum ...

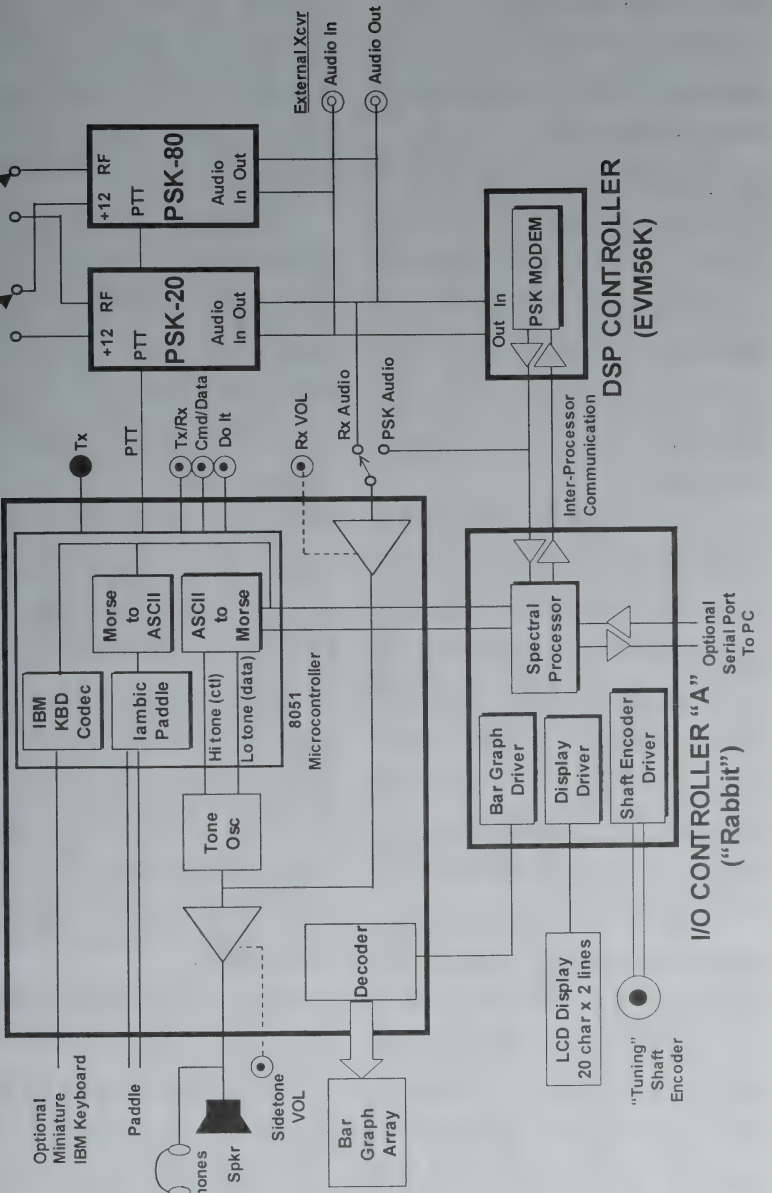


Fig. 3: Detailed System Diagram

LF to HF to VHF or beyond. The common denominator is the self-contained audio processing provided by this project, so any band that supports this communications mode is fair game!

The next thing to point out in the Detailed System Diagram is the separate nature of the PSK Modem block and the Spectral Processor block. Although the Simplified Block Diagram showed this as one functional block, they were implemented using two separate processor boards: the EVM56K board and a board called the "Rabbit".

The **PSK Modem function** is programmed into a standard, unmodified DSP56002EVM DSP controller board from Motorola. For all intents and purposes, the DSP code running on this board is the original design from G3PLX. The only implementation exception is that his PSK31.asm code module is placed into flash memory to allow self-booting without the need for an external PC on the serial port.

This board is a pretty neat project all unto itself. It formed the basis of many different amateur radio projects over recent years that have graced the pages of QST, QEX and RADCOM over the years in articles from the experts: KC7WW, G3PLX, KL7NA, and NA1DB. The Tucson Amateur Packet Radio (TAPR) organization even made a dedicated enclosure for the EVM board.

The PSK modulation/demodulation scheme used in the EVM56K board is a bit complex for the space we have here, but you can read the good description of Peter's DSP software in his two-part RadCom article. (See the detailed References section at the end of this article.)

Moving on now to the **Spectral Processor** bock, you'll see that it is implemented on a "Rabbit" microcontroller card. This is an inexpensive, fast, and self-contained processor and I/O board with which one can conveniently program in the C language. Significant time savings were achieved by using this board.

"Spectral processing" is the term I use to collectively refer to the higher-level processing tasks performed on the Rabbit controller board:

⇨ Accepting the raw modem pump "receive data" from the EVM board. A serial communications line connects the two boards and a command protocol is used to handshake between them. Blocks of data are exchanged, as defined in the header files of both source code listings.

⇨ Delivering the "transmit data" to the EVM board, as obtained from the IO Controller board.

⇨ Interpreting the data to determine phase and sync of the data. This is the heart of the modem pump operation, as implemented in DSP code. Described in detail in the G3PLX references.

⇨ Providing a graphical representation of the phase via the bar

graph array tuning indicators. A software driver updates the bar graph array through a serial bit stream protocol over to a serial-to-parallel shift register on the IO Controller board, which in turn drives the LED arrays.

⇨ Providing the frequency tuning, AFC tracking, and presetting capabilities. This is at the heart of the system, whereby the Rabbit controller notifies the EVM56K modem pump of changes in user-selected frequency (as received from the IO Controller), and keeps the DSP modem tracking to the locked-in frequency to compensate for system drift. (There is little-to-no Rx drift in the PSK-xx boards, but oftentimes the transmitting station drifts out of the narrow audio passband of the DSP, and this AFC feature tracks the station ... for a while, at least.)

⇨ Providing the file logging, data capturing and canned messaging. Various human interface features are provided in the Rabbit software to handle capture of received messages, transmit of special buffers or electronic files, like "my QTH is... Rag here is ...", etc.

⇨ Performing a lookup table conversion of the Varicode data. This is another of the core functions provided in PSK31 processing, as developed by Martinez, enabling the mode to be as efficient as it is at the relatively slow data rate.

⇨ Providing the resultant ASCII data ultimately to the user, by sending formatted serial commands over the command link to the "slave" IO Controller board, which in turn puts the data to the LCD, Morse annunciation, or to the optional external computer for logging and monitoring.

The software in this Spectral Processor board also originated from the G3PLX program called psk31.pas, which is software that normally runs on a PC and mates up with the modem pump software running on the EVM56K board. However with this Portable PSK project we converted the code to be run on a microcontroller, stripped out all of the conventional file I/O and screen user interface, and added a number of low-level human interfaces to allow it to operate in a small, self-contained box.

The last block in the system is the **"I/O Controller"** board. This is a custom-designed board which has an 8051-based microcontroller at its heart. This 8051 processor provides the Morse-ASCII-Morse conversions, keyer operation with the paddle, and optional keyboard input conversion.

The board contains two tone oscillators which are activated for Morse output of either data or status. Audio amplifiers are contained on this board to boost the level of the PSK receive data tones (more later on the valuable nature of these tones), and to provide the overall desired Morse output level. Serial data received from the Rabbit board is converted (serial-to-parallel decoding) in order to drive

the LED bar graph arrays.

The two boards (the Rabbit and the custom 8051 board) are referenced as I/O Controller Board A and B, respectively, in that they comprise the overall Supervisory Controller function in the system. These boards synchronize by means of an inter-board serial communication line. Special software is in place on the Rabbit to allow it to control the 8051 "B" board in a slave-like manner, thus simplifying some of the system software design.

Ultimately, one of the major improvements planned next for this project is a consolidation of the Rabbit's spectral processing functionality onto the 8051 board. This will provide an even more cost effective self-contained PSK solution. More on these "next steps" will be discussed toward the end of the article.

THE HUMAN INTERFACE

The "human interface" concerns the manner in which we use a given piece of equipment, and is often the most important part of the radios we all use. If the design of the radio's controls are intuitively obvious, easy to use, and relatively transparent, the experience of using that radio is greatly enhanced.

Conversely, if you have trouble in remembering how to use the various controls, constantly move your hands around in trying to control the basic parameters of the rig, or have difficulty seeing the numbers, letters or data, the overall feeling you have of the "box" ends up being not very good.

As an example of what I mean, I have a little DSP-controlled Ten-Tec shortwave receiver (RX-320) that has tons of features available on a "virtual front panel" provided by software running on the PC. I like the radio, but I find it very cumbersome to tune it, adjust its various controls, or have a good feel for where I am in the bands. Mouse interaction is not convenient for me when dealing with a radio. So as a result, I don't use the RX-320 as much as I do my big old Hallicrafters SX-110 receiver. A poor user interface will kill even the best of technology.

This consideration was paramount when I designed the human interface for the Portable PSK station. There are several clever features used in this project and on its front panel. I find them useful during use of the station, and others have commented on the unique approach to dealing with this mode's unusual characteristics.

The Tuning Display

The first thing one notices when turning on the unit is the apparently random flashing of the 20 little red LED bars contained in the two side-by-side bar graph arrays, as shown in figure 4a. Although the diagram shows a static random pattern of LEDs turned on, the real time display blinks rapidly in a random pattern.

The figure below it in 4b shows the LEDs lighted in a static and orderly manner, which indicates a tuned PSK condition. Let me explain the cause for this orderliness and how it's used by the operator to properly tune a PSK31 signal.

The Spectral Processor receives raw data from the EVM56K modem board containing the phase shift of the received signal. The value of the phase shift corresponds to a number between 0 and 360 degrees, based on a number of factors. The simple answer for now is that the phase indicates a frequency being received.

The constant stream of phase values coming from the modem board are continually output to the bar graph array display indicator on the front panel of the Portable PSK unit.

So just how does this indicate a tuned PSK signal, you ask? Well, we know that a PSK31 uses a "polarity reversal" modulation technique whereby phase reversal of the audio tone is effected when the digital data stream changes from a '1' to a '0' (and, of course, from a '0' to a '1'). At the receiving end, this process results in two tones that are 180-degrees out of phase with each other.

Figure 4a: Random LEDs = untuned PSK

Figure 4b: Matching LEDs = tuned PSK

Recalling that PSK31 modulation and demodulation process uses two tones (hence the characteristic "warble" heard from the receiver), the second tone is also analyzed by the EVM56K modem board. This yields yet another phase value coming across to the Spectral Processor.

When the phase difference of these two tones are displayed on a "radar scope"-type display, it looks as shown in figure 4c.

So finally, given that such a radar scope is difficult to easily and inexpensively put on the front panel of a radio, we do the next best thing ... we unwrap the radar

scope! Visualize snipping the circle of the radar scope at the top

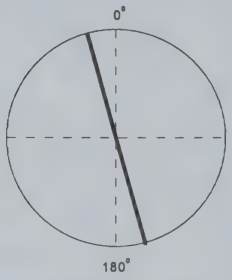


Figure 4c: Conventional 'rada scope' view of tuned PSK signal with its two components

(0-degrees), laying it down flat, and putting twenty LEDs along the line - ***voila***, you have our bar graph array tuning device shown in figure 4b!

Whenever a properly tuned PSK31 signal is present, only two LEDS will be on along that linear array. They may be as shown at 342 and 162, or at 324 and 144, or any other LED pair with a 180-degree difference. (Note that our granularity is 18-degrees when using an LED array with 20 positions.)

Another interesting point regarding the tuning characteristic is that when PSK31 stations start and end their transmissions, a single tone is usually transmitted for several seconds. This single tone shows up as a single and constantly illuminated LED that can be adjusted along our "linear" radar scope to be close to the 180-degree mark, as shown in figure 4d. For some reason that I don't understand, the PSK31 signals are best decoded when the steady carrier is at 180-degrees, and its corresponding out of phase signal is at 0-degrees.

The Tuning Control

A shaft encoder is used as the

Fig 4d: LED tuning indicator showing a single tone properly

main tuning control on the front panel. This component provides smooth and continuous adjustment of the "center frequency" being received and/or transmitted; hence it modifies the pattern of the LEDs shown on the Tuning Display.

Generally, one tunes a PSK31 radio by adjusting the spectral processing on the audio signal coming through the band pass of the particular radio being used. In our case the PSK-80 and PSK-20 boards from Small Wonder Labs have an audio bandpass of about 2 KHz, which means that an audio signal coming through the demodulation process of that transceiver will be somewhere in the range of 1000 Hz +/- 1000 Hz. Now its not too practical to get to close to the extreme ends of that bandpass filter curve (the slopes of the filters vary), but there can really be a lot of PSK stations contained within that window!

So the shaft encoder instructs

the internal spectral processor to move the center frequency away from the default starting point of 1000 Hz. During this tuning process, there is typical a wild random and bouncing LED pattern in the Tuning Display. But eventually, when a PSK31 signal is encountered the display will tend to "quiet down" and the LEDs will start settling into a pattern that is separated by 180 degrees. And when fine tuning adjustments are made, one is able to carefully move that 180-separated frequency pair indication along the linear array of LEDs. This is rather a fun process all unto itself! And as mentioned, it's best to adjust the display such that the constantly illuminated LED pairs are close to the 0- and 180-degree marks.

Various **options** exist in the configuration of the Portable PSK's tuning mechanism to provide:

⇨ variable tuning rates (in order to move faster than 1 Hz increments through the 2 KHz range),

⇨ 'memories' that can be called upon to save given locations within the range;

⇨ a 'search' algorithm that can automatically find PSK31 signals;

⇨ an 'AFC' algorithm that can lock on and track a given PSK31 signal (to compensate for drift).

These and other configurable options can perhaps be described in another installment of this project article.

"WYHIWYG"

As a derivative of a popular saying, in our "warbling" PSK31 world it is "**W**hat **Y**ou **Hear** **I**s **W**hat **Y**ou **G**et". In other words, you often can hear when a PSK transmission is coming into range, and it is helpful to be able to peak the audio within the narrow DSP modem processing window.

An audio level potentiometers is provided on the front panel for this purpose, and a small toggle switch gives it a dual purpose for the pot. Let me describe how these controls are used.

When the Audio switch is down, normal, unprocessed audio from the output of the PSK-xx board is fed into the audio amplification chain. This allows the operator to hear normal, wideband audio coming from the receiver section of the board. The Rx Audio pot adjusts the amplification of this signal, and the operator is able to hear the characteristic PSK warble while he is adjusting the Tuning Control.

Once the warble is tuned to the normal point (which you soon become adept at finding by ear!), the operator can flip the toggle switch up to the PSK Audio position and hear the very, very narrow bandpass filter output of the DSP modem processing. The output of this filter, when amplified, provides a pronounced audio peak in the received signal corresponding to a correctly tuned PSK signal. The Tuning Control and Tuning Display can then be adjusted

to provide correct phase placement of the signal in order to display the data coming across the link.

There is actually another audio level control on the front panel, labeled "Sidetone Audio". This is used as the master volume control for the amplification chain. It has the Morse annunciation tones mixed in and it can usually be set to a comfortable level and then left alone.

Well, I mentioned the next major element of the PSK rig's human interface (the use of Morse code) so let's get into it now.

Samuel B. Morse to the Rescue

An aspect that bugged me in my example of using the computer display of the Ten-Tec DSP receiver was the alternating use of the computer mouse and keyboard. It was distracting and just not intuitive. It wasn't a "radio".

Same too for all the conventional PSK interfaces available today. They're powerful but they just don't look or feel like a radio that I'm used to using. And they certainly aren't very convenient to lug along on my back while climbing the mountain.

So why not the obvious? Why can't we use Morse code to input data instead of typing it on a keyboard? And why can't we listen to Morse code data being played from the speaker? Should be just like listening to the trusty ol' Sierra QRP rig that I've been using for years, right?

Of course the answer is an emphatic YES for each of these situations. There are some obvious challenges (and some not so obvious) that need to be overcome, so let's get into it.

We'll need a basic Morse input and output "engine". There have been numerous articles, projects and kits in recent years describing how to construct Morse keyboards and Morse displays. These projects use a basic software element called a Morse-to-ASCII converter, or an ASCII-to-Morse converter.

ASCII is an acronym that represents the code for printable characters like those displayed on a computer screen or LCD display. It's a common coding scheme for the digital world and it's the kind of data that PSK31 systems send across the RF links. This is because computers have been classically used at both ends of the communications channel. It's a natural!

But it's <u>not</u> natural to interpret these ASCII-coded characters with the human ear. The ear <u>is</u> a good input device for Morse code, especially with our years of CW training between the ears. So the challenge is to use the right converter in our PSK transceiver to translate between the different worlds.

So I obtained and modified some software modules to perform the Morse-ASCII-Morse conversions and put them integrally in place as the primary input and output schemes for data as well

as commands.

Morse data input is the easy and obvious design to accommodate. A standard "keyer" software element is needed to accept the paddle as input and then convert the Morse character to its ASCII representation. The data character can then be displayed or sent to the PSK modem for ultimate transmission out the RF link. The Morse keyer output is also echoed through the audio chain as the "sidetone" to enable the operator to easily send with the normal feel of a CW rig.

Morse control input is similar to the data input design, except the commands entered are never modulated and sent out the RF link. They are instead used to command the transceiver and configure its memories, modes and states.

At this point it would be good to mention an interesting aspect in the use of Morse for both data and command.

With displayed characters there are all sorts of ways to distinguish data from commands on input, or data from status in output. Displayed characters can be placed in different locations of a screen, different colors can be used, different fonts and sizes can be used ... there indeed are many ways to distinguish data from command/status.

But **Morse audio output** is still Morse code, no matter how you cut it, right? NO! In this PSK transceiver we 'color' the Morse code in two ways: **speed** and **tone**.

Since the rate of characters going over the link is relatively slow, the Morse input (keyer speed) and Morse output (annunciation) functions are kept at the native slow speed of 10 wpm or so. And the frequency of the sidetone during Morse input, and of the sounded Morse during data reception, are both set somewhat lower (550 Hz). So data = "slow and low".

On the other hand, commands input and status output are distinguished by being sent fast (default of 25 wpm, but configurable), and at a higher pitch (750 Hz). So command/status = "fast and high".

Thus the ol' gray matter between the ears is able to lean back and interpret what's going on. Eyes closed, during the dead of night, or in bright sunlight ... this is indeed a human-friendly interface!

But there still is a curious aspect of using Morse annunciation with a data mode such as PSK. In a perfect world of perfect copy and near errorless transmission and reception, this scheme has potential. But how about on a **noisy link**?!

I must admit that this is problematic when trying to copy Morse code in the head with all sorts of nonsensical characters coming from the speaker. It's actually hard enough trying to read this garbage data on displays, but your brain is able to relatively easily "fill in the

blank", or even just skip over obviously garbled data.

But with garbled Morse annunciated data output, and especially when it comes at a slow rate, it's difficult to put the "big picture" together. In these instances it's best to hope for a good link. We also have a feature built into the modem software that only annunciates data when there is a solid sync present. In the cases with garbled data, the speaker would remain quiet. So far this seems to have worked pretty well.

LCD Display

As an assist to viewing the data and frequency settings of the PSK transceiver, an LCD display is provided on the front panel. It shows 2 lines of textual information with 20 characters in each line.

The top line of the display is dedicated for data - received data when receiving, and transmit data was transmitting. It presents the data in a left-to-right movement similar to that seen in a stock ticker tape display. Once scrolled off the left side, data is lost unless logging is enabled to capture the data to a file or to the auxiliary serial port on the back panel.

The bottom line of the display is used to display a variety of information. The left side shows the current mode and state of the internal processing, and to provides a prompt for command input by the operator. The right side is used to display the center frequency of the transceiver.

The Rest of the Story

As illustrated in figure 1 back on the first page of this article, the remaining controls and connections on the **front panel** include:

⇨ Tx/Rx Pushbutton - provides a means to manually put the PSK transceiver into transmit mode. The contents of any unemptied buffer is sent, and then data continues to be sent until the pushbutton is actuated again to put the rig back into receive mode.

⇨ Tx LED - this is illuminated when the PSK transceiver is in transmit mode, either through manual means (Tx/Rx Pushbutton), or automatically if the "VOX" mode is enabled.

⇨ Command/Data Pushbutton - signals the internal I/O Controller to next accept either command or data from the user. The respective command or data state is displayed in the bottom left line of the LCD.

⇨ Do It Pushbutton - This is used to initiate action set up via a previously-issued command. For example, actuating Do It may be used to send the contents of a buffer containing QTH information.

⇨ Key Jack - accepts the paddle as the main data input and control device of the operator.

⇨ Phone Jack - accepts a standard headphone for quiet listening or for external amplification.

As illustrated below in figure 5, the **rear panel** sports the fol-

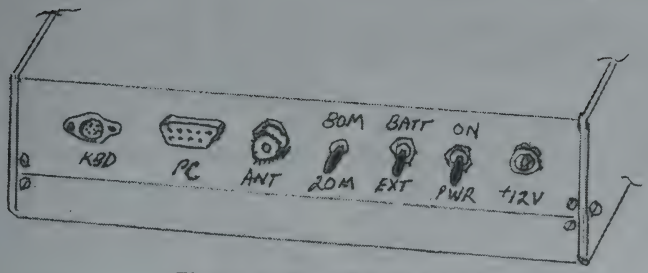


Figure 5: Rear Panel Interface

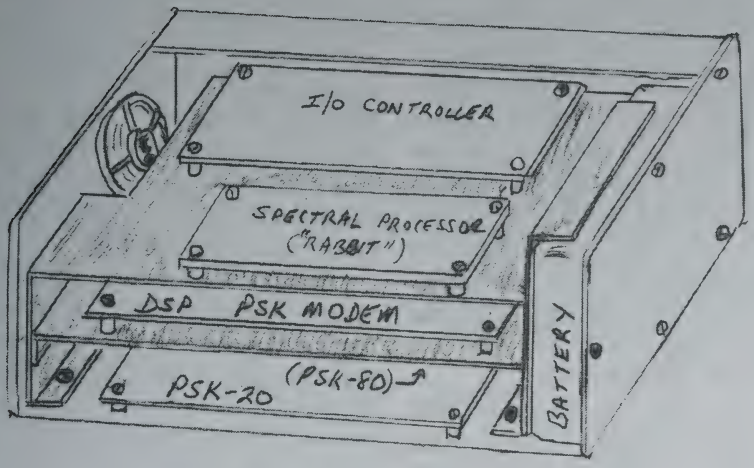


Figure 6: Physical Construction

lowing complement of interfaces.

+12V - a 2.1mm coaxial power jack is used to input +12-14.5V DC power source.

Power ON - switches in the selected DC power source.

Batt/Ext - selects either the internal battery or the external DC input as the power source for the PSK transceiver. The battery is charged when the main power switch is off if an external supply is connected.

80/20m - selects the desired transceiver by applying power to it and switching its RF to the rear panel antenna jack.

ANT - the antenna gets plugged into this jack

AUX - This is the auxiliary serial port through which data may optionally be directed. (e.g., for data logging, remote computer control, etc.)

KBD - accepts a standard AT-style PC board as an optional data in-

put means. (There are some attractive miniature keyboards that might even be applicable for field operation.

PHYSICAL CONSTRUCTION

Given a pretty strong design requirement of being "portable", I felt compelled to ensure that even the prototype unit was constructed in a small form factor.

At this infant stage, the Portable PSK transceiver consists of five boards that needed to be packed into a small enclosure. Referring to figure 5, I took the approach of creating three layers of circuit boards, using bare copper-clad pc board material as the decks. I was thinking that I might need to make each deck somewhat "RF tight" to reduce the computer's EMI from interfering with the transmitted/received signal (or vice versa), but it turned out to be unnecessary.

The two PSK-xx transceiver boards are located on level 1, the EVM56K DSP board is located on level 2, and the pair of microcontroller boards (the Rabbit Spectral Processor and the 8051 I/O Controller) are contained on level 3.

Tucked along the side of the enclosure is a sealed lead-acid 12 volt battery to provide some amount of off-mains operation. As the project evolves, some boards will combine into one and better economy of power can be realized.

SCHEMATIC

The I/O Controller Board is the only homebrew circuit board, and even this is relatively straightforward in design, as shown in figure 7. [The schematic is found in the inserted centerfold section]

All of the "smarts" are included in the 8051 microcontroller software. Pushbuttons, LED, serial port and PTT "keyline" are all controlled by basic bit manipulation.

Individual bits also turn on/off the two separate tone generators composed of the 74HC240 inverter gates operating in linear mode as oscillators. These audio waveforms are combined with the amplified PSK data signals at the input of the LM386 amplifier, used to drive a small speaker.

Even thought he 8051 processors are relatively garden variety these days, I feel compelled to explain my use of the Dallas Semiconductor version. I've been using the DS5000T device for many years, although it's a bit expensive (~$30), it provides an excellent developer platform with it's flash (nonvolatile) memory and its ability to have new programs downloaded directly to it. No removal for programming via a special programmer, no UV erasure lamps, nothing. And with 8K of memory space, three full parallel I/O ports, PWM generator, A/D port, interrupts, built-in serial port, yada yada yada ... this makes a super friendly development system. Later, as the design matures, and if the project ever proliferates in

the form of a published design or manufactured rig, the DS5000T's 8051 sourcecode can be easily ported over to a garden variety $2.95 one-time-programmable 8051 chip.

Buttoning it Up for Now

This is just the first incarnation of a very big and extensible project. There is so much more work and optimization to be done. And most importantly, I need to get on the air a lot more using the rig than I have been able to do during the development of it.

Similarly, there are many natural evolution steps for the technology, features and options. This is an engineers dream box - the flexibility available, and the configurability possible with this design are almost limitless.

One of the more pressing evolutionary upgrades needed is the replacement of the EVM56K DSP board. This evaluation board is no longer available, but there is an equally attractive development board from Analog Devices that should be relatively straightforward to port to. By doing this, more hams will be able to reproduce the design and help move it forward.

Overall, this has been a tremendously exciting design to be working on, and one in a technology area that has the involvement of a growing number of hams and technologists. Being able to provide some "new legs" for a hot technology like PSK31 is truly fun. And actually using it is even better!

ACKNOWLEDGEMENTS

I mentioned early on the uncles and many cousins upon whose shoulders I'm standing in being able to do this work. The guys I refer to are Peter Martinez G3PLX, Johan Forrer, KC7WW, and Rob Frohne, KL7NA. Each of these very bright individuals helped and advised me along the way, either through direct contact or in their published works.

Next there is the "PSK Team", as I refer to it, here on the east coast: Dave Benson, NN1G, Skip Teller, KH6TY/4, and Joe Everhart, N2CX. These guys have been instrumental in my mastering of the PSK technology, performing countless hours of online and in-person tests, late night phone calls and frantic email cries for help. They are truly giants in my eyes.

Additionally, Dave Benson has got to be one of the kindest, smartest and most benevolent gentlemen in ham radio today. His work with the QRP community as a supplier (owner of Small Wonder Labs), as a designer and technician, and as a technical leader in the newer technologies is unrivaled.

I've found that there are only very few times when the things align just right in the universe to be called serendipitous (at least for me). But I was able to call upon another of our innovative cousins in the QRP community: Steve

Webber, KD1JV, who had just finished a design that could serve as the exact data conversion engine needed for this Portable PSK transceiver project. His "Deluxe LCD Keyer" had the basic Morse-to-ASCII-to-Morse conversion engines implemented in software and he graciously agreed to share the source code with me for use in this project. I extracted the portions needed and fit it into the I/O Controller board. Thanks a million Steve.

Finally, I applaud the ARRL and its QST staff for pushing forward on PSK31 and encouraging all the experimenters in the ham ranks. Their constant flow of great technology articles and responsive communications goes far beyond the value of the written word. Thank you!

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